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# **Supporting Documentation Materials for HACCP Decisions**

**Prepared for the Food Safety and Inspection Service  
U.S. Department of Agriculture**



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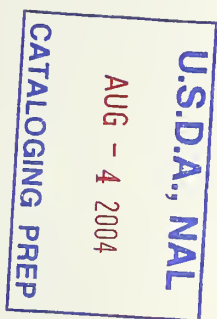
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# Introduction

This material has been developed to aid you, the meat and poultry processor, in the scientific documentation of the HACCP decisions during hazard analysis, validation of plans, and corrective actions by giving examples of processing steps from scientific publications and regulatory documents. Organized by HACCP process category, this material will assist you after your specific hazards and critical control points of your process(es) have been identified. The table of contents on the previous page will direct you to the location of each process category. Be advised that not all possible hazards are covered in this manual, and many steps that are included in this information may not necessarily be hazards in your process.

This manual includes published scientific research. The research that has been done does not necessarily comply with current regulations, nor are all of the parameters normal processing conditions. Some of the treatments discussed are not within the legal limits; other treatments may not be approved at any level. Some of the research in this manual shows that certain conditions are not effective in reducing or eliminating risk; other conditions may create a probable risk. This information is here not only to validate existing processes, but also to demonstrate the effectiveness, or lack thereof, of process steps that may be added to your process in the future.

Much of the information included here focuses on biological hazards. Physical and chemical hazards are addressed, but only briefly. One topic of major interest in the food industry as a whole is allergens. Allergens are not a defined class of substances, but there are 8 categories of foods that have been scientifically recognized and accepted by the United Nations Joint Food and Agriculture Organization (FAO) and the World Health Organization (WHO) Food Standards Programme in 1995. These categories are: Cereals containing Gluten; Crustacea; Eggs and egg products; Fish and Fish products; Peanuts; Milk and Milk products; Tree nuts; and Soybeans. Foods in these main categories affect people in two main ways. Food intolerances are a reaction to the chemical composition of the food itself. Food sensitivities are immune responses the body has to proteins in the food. Either manner that a person reacts to an allergen is highly individualistic, varying in degree, onset time, location of reaction and the amount of the food needed to trigger the response. Because of this concern, it is important that processors think “up front” about allergens and the possibility of cross-contact between products that may have allergens labeled and those that do not. It is also of utmost importance that all ingredients are correctly labeled on products, especially those ingredients that contain protein such as those listed in the 8 categories above.



The information from published articles has been compiled into the following tables for the easiest use. Once you find the correct process category, the table will help you find the specific step you wish to document. Again, there are many steps listed that may not apply to your process, and specific steps in your process may not be included. The first column, labeled “**Process Step**,” in the table indicates the point or step of each process flow, in which scientific or regulatory documentation is available. Not all steps in a process will be found here, and individual processors may have other process steps in their HACCP plans; the processes listed here have been specifically addressed by scientific research. The second column identifies the “**Potential Hazards**” that have been addressed in published scientific literature for each process step. The third column, labeled “**Process Parameters**,” describes the conditions that are applied in various scientific publications. This table is designed so that a processor can go to the processing point or step of interest, then move across to the potential hazards and process parameters that best match their particular process. The reference will only be valid if the steps you take match the criteria in this column. The column lists the specific product that was tested. If you are looking for turkey information, broiler information may not necessarily apply. If you are processing pork, beef information may not apply. Upon identifying one or more process parameters that are appropriate for the operation, the fourth column, labeled as “**Decision Criteria**,” will describe the results of the research, or the regulatory requirements. In the fifth, or last column, labeled “**Scientific Documentation**,” the actual source of the information described in the three columns to the left is listed.

<b>Process Step</b>	<b>Potential Hazards</b>	<b>Process Parameters</b>	<b>Decision Criteria</b>	<b>Scientific Documentation</b>
This column indicates the point or step of each process flow, in which scientific or regulatory documentation is available.	This column identifies the potential hazards that have been addressed in published scientific literature, for each process step.	This column describes the conditions used in the research that is described in various scientific publications.	This column describes the results of the research, or the regulatory requirements.	This column describes the actual source of the information, described in the three columns to the left. Where available, a website is given to allow internet access to publications.



Where available, a website is given to allow internet access to publications. If a website link is not provided, publications can be accessed from either the National Agricultural Library (Website: <http://www.nal.usda.gov/>, E-mail: [lending@nal.usda.gov](mailto:lending@nal.usda.gov) or phone: 301/504-5879) or through inter-library loan, at your local library. When requesting publications at either location, you will need to provide the information that is listed under the column “**Scientific Documentation**” (author, title, year, journal name, volume, page numbers, etc.).

The following is an example of how one might use this manual:

You need to validate or examine the decision you made to select the critical limit that you have chosen for the cooking step in a Fully Cooked, Not Shelf Stable HACCP plan. You would go to the Fully Cooked, Not Shelf Stable Process section (see page 54) and look for “cooking” in the far left column, **Process Step** (see page 67). Next, look at the second and third columns (**Potential Hazards** and **Process Parameters**) to find hazards and processing procedures that match what you are doing. Once you have found **Process Parameters** that fit your process, read the **Decision Criteria** in the next column to the right to find the results of published research that should help you in your decision. Finally, the **Scientific Documentation** column will give the information that you would need if you wanted to read the entire article. If the process parameters do not fully match your specific process, a further review of published research is necessary.

This is a living document. New research is continually being published and other publications are always being brought to our attention. Though this compilation is extensive, it is not exhaustive. Our intentions are to update this manual regularly and the updated versions will be available at The Ohio State University Meat Science web page at: <http://www.ag.ohio-state.edu/~meatsci/HACCPsupport.html>



# Glossary



**Aerobic** - Bacteria that require oxygen to grow or will grow in the presence of oxygen.

**Anaerobic** – Bacteria that do not utilize oxygen to grow, or will not grow in the presence of oxygen.

**Bacteriocin** – A substance that is produced by specific bacteria that is toxic to closely related strains of the same specific bacteria and either kills or slows the growth of those other specific bacteria.

**Coliform** – Bacteria that most often inhabit the intestine of animals, do not utilize oxygen, but can grow in its presence. Bacteria that are classified as coliforms have the same shape, and many of the same characteristics. These bacteria are used as indicators of sanitary quality in many food products.

**Detection limit** – The lowest threshold amount of bacteria that must be present in a sample to be found. Detection level depends upon methods used.

**Direct plating** – The application of a sample, or dilution thereof, to solid media usually containing agar and other material used to grow and enumerate bacteria.

**D-value** – The amount of time needed to destroy one log unit of a specific bacteria at a specific temperature in a specific medium.

**Enrichment** – Addition of nutrient rich broth so that certain bacteria or type of bacteria increases in number to result in a bacterial cell count that is higher than the detection limit. This is used to detect only the presence or absence of the bacteria, not the amount present.

**Enterobacteriaceae** – Large group of bacteria that are closely related and are commonly found in fecal material of warm blooded animals. They include coliforms and pathogens such as Salmonellae.

**F-value** – Measured in minutes, the D-value of a specific organism at 250°F (121°C) multiplied by the desired log reduction.

**Germination** – The process of a spore becoming a vegetative cell.

**Inhibition** – The slowing or stopping of bacterial growth.

**Lag time** – Time that bacteria take to become acclimated to a new environment before starting to multiply. Bacteria divide and their numbers grow exponentially, 1 becomes 2 becomes 4 becomes 8.

**Lethality** – The effectiveness of a treatment to destroy or kill bacteria.



## Glossary

**Log unit** – A unit of  $10^x$  used to count bacteria. The difference between  $10^6$  (1,000,000) and  $10^7$  (10,000,000) is one log unit (9,000,000), the difference between  $10^6$  and  $10^5$  (100,000) is also one log unit (900,000).

**Mesophiles** – Bacteria that have optimum growing temperatures between 77°F (25°C) and 104°F (40°C).

**Microflora** – Bacteria, molds and yeasts.

**Pathogen** – Organisms that cause illness. These organisms include bacteria, protozoa, or viruses.

**pH** – Level of acidity or alkalinity in a product. The pH scale ranges from 1 to 14 with 7 considered neutral, 1 the most acidic and 14 the most alkaline. Fresh meat usually has a pH near 5.6.

**Psychrotrophs** – Bacteria that have optimum growing temperatures between 68°F (20°C) and 86°F (30°C) but can grow at temperatures as low as 32°F (0°C).

**Residue** – Usually refers to the presences antibiotics or pesticides that are still detectable in carcasses at slaughter.

**Shocked (heat shocked)** – Occurs when a product is heated but the temperature is not high enough to destroy the bacteria. This results in bacteria that are injured for a while but in most cases can repair itself and becomes more resistant to heat the next time the product is heated. Heat shocked can also refer to the process by which a spore is induced into germination. When a product is heated thoroughly the vegetative cells are destroyed, but the spores are undamaged by the heat. The spores then germinate into vegetative cells once the temperature has decreased to an optimum level.

**Significant difference** – Statistical difference in results due to treatments.

**Spore** – A highly resistant, dormant form that some bacteria can change into. Spores are usually very resistant to heat, long periods of dryness, and other adverse conditions that normal vegetative cells cannot survive. Most must be heat shocked to germinate into normal, vegetative cells. Most of the time spores have a toxin associated with them, either within the spore covering, or released at the time of germination or when becoming a spore (sporulation).

**Strain** – A specific subset of bacteria. For example, *Escherichia* is the genus, *coli* is the specie and **O157:H7** is the strain.

**Thermotolerant** – Bacteria that can withstand higher than normal temperatures.

**Toxin (enterotoxin, mycotoxin, neurotoxin)** – A compound produced by a bacterium or fungi (molds and yeasts) that can cause illness in other living organisms. Specific examples include enterotoxins which affect the intestine, mycotoxins are those toxins produced by fungi, and neurotoxins attack the nervous system.



## Glossary

**Transdermal synergists** – Compounds that work with other compounds against bacteria when applied to the surface of a carcass.

**Treatment** – The method of processing that is being tested. A good research study will compare various treatments, such as levels of salt in a product, to a control, in this example the control maybe no salt added. All other conditions should remain the same for all samples tested except the specific treatment.

**Vegetative cell** – The normal bacteria cell. This is in contrast to a spore. Vegetative cells are susceptible to destruction or damage from heat, additives, and other factors that can damage and destroy them relatively easily.



# **Bacteria and Parasite**



***Aeromonas hydrophilia*** – A pathogenic psychrotroph that produces an enterotoxin.

***Bacillus cereus*** – A spore-forming, pathogenic bacterium that forms an enterotoxin. *B. cereus* is an aerobic spore-former, unlike the common clostridium spore formers which are anaerobic.

***Campylobacter jejuni*** – A common pathogenic bacterium that forms an enterotoxin. It needs very low levels (about 5%) of oxygen and too much will inhibit growth, and about 10% carbon dioxide is required for growth. *Campylobacter* is the most common cause of food borne illness in the United States, commonly associated with diarrheal illness.

***Clostridium botulinum*** – A spore-forming, pathogenic bacterium that forms a neurotoxin when in an anaerobic environment. *C. botulinum* is a concern mainly in canned foods.

***Clostridium perfringens*** – A spore-forming, pathogenic bacterium that forms an enterotoxin in the spore coat. *C. perfringens* must be ingested in large quantities while a vegetative cell and then will sporulate in the intestine.

***Clostridium sporogenes*** – A spore-forming, non-pathogenic bacterium that mimics other clostridium bacteria in growth conditions. *C. sporogenes* is often used in research where use of the pathogenic bacteria is infeasible.

***Escherichia coli*** – A common coliform bacterium. Generic *E. coli* is used as an indicator bacterium for fecal contamination. The strains O157:H7 and O128 are among the few strains of *E. coli* that have been found to be pathogenic. These two strains have different growth characteristics than generic *E. coli*, and must be detected using different methods.

***Lactobacillus plantarum*** – A non-pathogenic bacterium that is commonly used in starter cultures. *L. plantarum* and many other *Lactobacillus* species are noted for their production of lactic acid, which lowers pH and gives distinctive flavors.

***Leuconostoc*** – A non-pathogenic bacterium that is used in starter cultures. *Leuconostoc* species produce lactic acid used to lower pH and give distinctive flavors.

***Listeria monocytogenes*** – A pathogenic bacterium that grows well in many adverse conditions. *L. monocytogenes* is considered a psychrotroph, and likes to grow in damp cool places such as drains and on floors. *L. monocytogenes* is the only species of *Listeria* that is considered pathogenic. Presence of *L. monocytogenes* on carcasses is usually attributed to contamination by fecal matter during slaughter.

***Pediococcus acidilactici*** – A non-pathogenic bacterium that is used in starter cultures. *P. acidilactici* produces lactic acid, which lowers pH and produces distinctive flavors.



**Salmonellae, *Salmonella* spp., *S. seftenberg*, and *S. typhimurium*** – A pathogenic bacterium that is a common cause of gastrointestinal foodborne illness. Salmonellae grow rapidly in optimum conditions and all of the numerous species are considered pathogenic. Other notable *Salmonella* species are *S. typhi*, which causes Typhoid fever, and *S. enteritidis*, a frequently occurring specie, second only to *S. typhimurium*.

***Staphylococcus aureus*** – A pathogenic bacterium that produces a very heat stable enterotoxin known for producing severe abdominal cramps, vomiting and diarrhea in humans.

***Trichinella spiralis*** – A parasite (round worm) that lodges in certain muscles while in the larva form. *T. spiralis* is of most concern with pork, however it can be found in other game meats such as bears, canines, and marine mammals, that consume meat.

***Yersinia enterocolitica*** – A pathogenic bacterium that is commonly found in the lymph system of the pig. *Y. enterocolitica* is a psychrotroph and produces an enterotoxin.



# Physical Hazards

This category crosses all process categories.

It includes lead, other metals, glass, and any other physical hazards that may occur.



Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
All process steps	P – Any foreign material	Opportunity for any physical contamination to occur	Monitoring equipment must be sensitive enough to detect contamination as small as 1/32” (0.8mm). The presence of any visible foreign material needs to be addressed. Visual inspection is a necessity when no other metal detection or x-ray devices are employed. A visible inspection is prudent in addition to machines due to the nature of detection devices and the many types of materials that may cause a physical hazard.	FSIS directive 7310.4 Revision 2, 12/28/93  This directive has been cancelled, however, it provides a basis for contamination monitoring.
	P and/or C – Lead hazard	Contamination of muscle tissue with lead shot	<p>Though whole lead shots are removed from the meat, a trace amount of residue remains. However, the amount of lead residue is not of health concern unless excessive amounts of the contaminated product are eaten daily over a long period of time.</p> <p>Although scientific documentation is limited it is advised that processors are aware that lead toxicity is always a concern and should be addressed.</p>	<p>Burger, J., R.A. Kenamer, I.L. Brisbin Jr., and M. Gochfeld. 1997. Metal levels in mourning doves from South Carolina: potential hazards to doves and hunters. Environmental Resources. 75 (2) 173-186.</p> <p>AND</p> <p>Johansen, P., G. Asmund, and F. Riget. 2001. Lead contamination of seabirds harvested with lead shot – implications to human diet in Greenland. Environmental Pollution. 112 (3) 501-504.</p>



# **Slaughter Process**

Includes: beef, and pork



# Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Animal Receiving/holding	C – Antibiotic and pesticide residues	Slaughter of hogs and cattle	There have been “no reports of residue-related human illness in the United States associated with consumption of commercially available meat or poultry.” Monitoring for the presence of violative chemical residues is done by USDA and the slaughter establishments. Industry educational programs such as the Pork Quality Assurance (PQA) Program (National Pork Producers Council, 1994) have promoted residue prevention on the farm. In addition to the end producer efforts to address residues, slaughter establishments can request letters of guarantee and copies of relevant animal treatment records (Pork Slaughter model, Draft USDA FSIS April, 1997).	Kindred T. P., and W.T. Hubbert. 1993. Residue prevention strategies in the United States. Journal of the American Veterinary Medicine Association. 202 (1) 46-49.
			There is a low risk of antibiotic and pesticide residues in meat.	National Residue Monitoring program, 1999.  To access on the internet: <a href="http://www.fsis.usda.gov/OPHS/red99/">http://www.fsis.usda.gov/OPHS/red99/</a>



# Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Animal Receiving/ holding	B –Contamination with <i>Salmonella</i> spp., <i>Listeria monocytogenes</i> , <i>Campylobacter</i> spp., <i>Clostridium perfringens</i> , and <i>Yersinia enterocolitica</i>	Co-mingling and resting of animals prior to slaughter	Feed withdrawal and holding animals 2 to 6 hours prior to slaughter has been shown to reduce the incidence of ruptured viscera and cross-contamination.	Miller, M.F., M.A. Carr, D.B. Bawcom, C.B. Ramsey, and L.D. Thompson. 1997. Microbiology of pork carcasses from pigs with differing origins and feed withdrawal times. Journal of Food Protection. 60 (3) 242-245.
	P – Foreign material	Slaughtering animals with the possible presence of needles, buckshot etc.	There is a low incidence of occurrence.	National Beef Quality Audits, 1991, 1995, 2000.
Pork carcass scalding	B – <i>Escherichia. Coli</i> , <i>Salmonella</i> and <i>Campylobacter</i> survival	Scalding in water at or below 145°F (63°C)	<i>E. coli</i> , <i>Salmonella</i> and <i>Campylobacter</i> were not killed with 122°F (50°C) water typical in a scalding tank. The carcasses must still be singed to kill the pathogens.	Gill, C.O., and J. Bryant. 1993. The presence of <i>Escherichia coli</i> , <i>Salmonella</i> and <i>Campylobacter</i> in pig carcass dehairing equipment. Food Microbiology 10 (4) 337-344.
		Scalding in water to 145°F (63°C)	<i>E. coli</i> , <i>Salmonella</i> and <i>Campylobacter</i> are killed at 145°F (63°C).	
		Scald water at less than 140°F (60°C)	<i>Salmonella</i> spp. were only found when scald water was less than 140°F (60°C).	Kampelmacher, E.H., P.A.M. Guinee, K. Hofstra, and A. Van Keulen. 1961. Studies on <i>Salmonella</i> in slaughter houses. Zentralbl. Veterinaarmed. Reihe. 8:1025-1032.



Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Beef carcass pre-evisceration and evisceration	B- Fecal contamination with <i>E. coli</i> O157:H7, and <i>S. typhimurium</i>	Post hide removal, pre-evisceration wash of beef carcasses with distilled (not tap) water	A pre-evisceration wash makes the surface of the carcass less tactile, therefore allowing any ensuing contamination easier to remove. <i>E. coli</i> O157:H7, and <i>S. typhimurium</i> count was 0.7 log units less after washing.	Dickson, J.S. 1995. Susceptibility of preevisceration washed beef carcasses to contamination by <i>Escherichia coli</i> O157:H7 and salmonellae. Journal of Food Protection. 58 (10) 1065-1068.
Hide removal/ evisceration	B- Fecal contamination with <i>E. coli</i> , and Enterobacteriaceae	Steam vacuuming beef carcasses at 162°F (72°C), followed by a hot water spray of 203°F (95°C), at 24 psi, and/or an 11 second spray of 2% lactic acid at 131°F (55°C)	Fecal contamination will be removed by steam vacuuming when accompanied by either or both of the hot water or lactic acid treatments. <i>E. coli</i> , Enterobacteriaceae, and total and thermotolerant coliforms were consistently reduced to less than 1.0 log.	Castillo, A., L.M. Lucia, K.J. Goodson, J.W. Savell, and G.R. Acuff. 1999. Decontamination of beef carcass surface tissue by steam vacuuming alone and combined with hot water and lactic acid sprays. Journal of Food Protection. 62 (2) 146-151.
	B- Fecal contamination with <i>E. coli</i> , and <i>S. typhimurium</i>	Rinse beef carcasses with low pressure (10 psi), followed by high pressure (250 psi) 95°F (35°C) water	After a known fecal contamination, washing with water reduces the <i>E. coli</i> O157:H7, and <i>S. typhimurium</i> by 2.6-3.0 log units; however, it allows bacteria to be spread to the area outside of the visible contamination area.	Hardin, M.D., G.R. Acuff, L.M. Lucia, J.S. Oman, and J.W. Savell. 1995. Comparison of methods for decontamination from beef carcass surfaces. Journal of Food Protection. 58 (4) 368-374.
		Trimming visible contamination from beef carcasses	Trimming away contamination was equivalent to water washing in reducing visible contamination and more consistent in reducing <i>E. coli</i> O157:H7 to non-detectable levels than washing with water. However, contamination was still detectable outside of the initial area that was visibly contaminated.	



Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Hide removal/ evisceration	B- Fecal contamination with <i>E. coli</i> , and <i>S. typhimurium</i>	Rinse beef carcasses with low pressure (10 psi) followed by high pressure (250 psi) 95°F (35°C) water, then spraying the area with a fine mist of 131°F (55°C) 2% acetic acid for 11 seconds	The addition of the 2% acetic acid treatment with the water wash, reduced <i>E. coli</i> , and <i>S. typhimurium</i> count 2.4 to 5.1 log units inside the contaminated area and to < 0.5 log units outside the initial contamination area to below detection level more effectively than just the water wash, or trimming.	Hardin, et al. 1995 cont'
		Rinse beef carcasses with low pressure (10 psi) followed by high pressure (250 psi) 95°F (35°C) water, then spraying the area with a fine mist of 131°F (55°C) 2% lactic acid for 11 seconds	The addition of the 2% acetic acid treatment with the water wash, reduced <i>E. coli</i> , and <i>S. typhimurium</i> count 3.0 to 5.0 log units inside the contaminated area and to < 0.5 log units outside the initial contamination area to below detection level more effectively than just the water wash, or trimming.	
	B – <i>S. typhimurium</i> contamination	Spraying pork carcasses with 2% or greater lactic acid solution at 52°F (11°C) for at least 60 seconds.	The cold lactic acid treatment eliminated <i>S. typhimurium</i> when contaminated with 1 log unit but was less than 50% successful in removing contamination when inoculated with 2 log units.	Van Netten, P., D.A.A. Mossel, and J. Huis In't Veld. 1995. Lactic acid decontamination of fresh pork carcasses: a pilot plant study. International Journal of Food Microbiology. 25 (1) 1-9.



Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Hide removal/ evisceration	B – <i>S. typhimurium</i> contamination	Spraying pork carcasses with 2% or greater lactic acid solution at 131°F (55°C) for at least 60 seconds	The hot lactic acid treatment eliminated <i>S. typhimurium</i> when contaminated with up to 2 log units.	Van Netten et al. 1995 cont'
	B – Contamination with <i>Salmonella</i> , <i>Yersinia</i> , and <i>Campylobacter</i>	Spray pork carcasses with 1/5% acetic, citric, or lactic acid	No significant microbiological difference was made with these treatments on <i>Salmonella</i> , <i>Yersinia</i> , and <i>Campylobacter</i> .	Fu, A.H., J.G. Sebranek, and E.A. Murano, 1994. Microbial and Quality Characteristics of Pork Cuts from Carcasses Treated with Sanitizing Sprays. Journal of Food Science. 59 (2) 306-309.
	B – Contamination with <i>Salmonella</i> spp., and <i>Campylobacter</i> spp.	Spray pork carcasses with 2% lactic acid spray (20 psi, ca. 150 ml per half carcass)	Incidence of <i>Salmonella</i> spp. and <i>Campylobacter</i> spp. decreased 95 to 99% with this treatment.	Epling, L.K., J.A. Carpenter, and L.C. Blankenship. 1993. Prevalence of <i>Campylobacter</i> spp. and <i>Salmonella</i> spp. on pork carcasses and the reduction effected by spraying with lactic acid. Journal of Food Protection. 56 (6) 536-537.
	B – aerobic and anaerobic pathogen survival and growth	Spray pork carcasses with 55°F (12.8°C) tap water followed by 2% acetic acid solution at 55°F (12.8°C) both at 200 psi	There was a 0.8 log decrease in the microflora present one hour after treatment, and the inhibition continued through the 28 <sup>th</sup> day of storage when there was a 0.9 log difference between those loins sprayed with acetic acid and those not sprayed at all. Over all there was still a 4 log growth over the 28 days for all treatments.	Cacciarelli, M.A. W.C. Stringer, M.E. Anderson, and H.D. Naumann. 1983. Effects of washing and sanitizing on the bacterial flora of vacuum-packaged pork loins. Journal of Food Protection. 46 (3) 231 – 234.



## Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Hide removal/ evisceration	B – aerobic and anaerobic pathogen survival and growth	Spray pork carcasses with 55°F (12.8°C) tap water followed by 200 ppm sodium hypochlorite solution (adjusted pH to 6.0 with phosphoric acid) at 55°F (12.8°C) both at 200 psi.	A 0.6 log reduction was detected one hour after treatment, however by 21 days after slaughter there was no difference in growth between those sprayed with sodium hypochlorite solution and those that were not sprayed at all (approx. 6.9 log count of microorganisms).	Cacciarelli et al. 1983 cont'
		Spray pork carcasses with 55°F (12.8°C) tap water at 200 psi.	A 0.6 log reduction was detected one hour after treatment, however by 21 days after slaughter there was no difference in growth between those sprayed with water and those that were not sprayed at all. (~6.9 log count of microorganisms).	
Dehairing	B- <i>Salmonella</i> contamination	No post-dehairing rinse of pork carcasses	Carcass sides should be washed with high-pressure spray inside and out and immediately placed in chill room with minimal handling and the meat temperature maintained at or below 45°F (7.1°C) to reduce the prevalence of <i>Salmonella</i> .	Newel, K.W., and L.P. Williams. 1971. The control of <i>Salmonella</i> affecting swine and man. Journal of the American Veterinary Medical Association. 158 (1) 89-88.
		Post-dehairing rinse of pork carcasses		
	B- <i>E. coli</i> survival	Rinse polished pork carcasses for 40 seconds with water at 140°F (60°C) or less	This treatment results in approximately a 2 log reduction of bacteria including <i>E. coli</i> .	Gill, C.O., D.S. McGinnis, J. Bryant, and B. Chabot. 1995. Decontamination of commercial polished pig carcasses with hot water. Food Microbiology. 12 (2) 143-149.



# Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Dehairing	B- <i>E. coli</i> survival	Rinse polished carcass for 40 seconds with water at 167°F (75°C) to 194°F (90°C)	Treatment resulted in a 4 to 8 log reduction of bacteria. (However, the carcass was discolored).	Gill, et al. 1995 cont'
		Rinse polished carcass for 40 seconds with water 185°F (85°C)	Treatment resulted in 1 to 3 log reduction of <i>E. coli</i> .	
Evisceration, head trimming	B- <i>Yersinia enterocolitica</i> contamination	Circumanal incision and removal of intestines; excision of the tongue, pharynx, and the tonsils; incision of the mandibular lymph nodes and deboning of head meat	Prevent <i>Yersinia enterocolitica</i> contamination as the organism is able to grow in refrigerated foods.	Kapperud, G. 1991. <i>Yersinia enterocolitica</i> in food hygiene. International Journal of Food Microbiology. 12 (1) 53-66.
	B – <i>E. coli</i> , coliforms and aerobic bacteria contamination	Washing carcasses with water at 104°F (40°C) and pH 7.5 and trimming after skinning and evisceration of beef carcasses	<i>E. coli</i> , coliforms and aerobic bacteria deposited on surface during skinning and evisceration are not reduced by trimming, and washing.	Gill, C.O., M. Badoni, and T. Jones. 1996. Hygienic effects of trimming and washing operations in a beef-carcass-dressing process. Journal of Food Protection. 59 (6) 666-669.



Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Final Trim	B – Fecal, milk and ingesta contamination to carcasses	Final trim of beef, pork and lamb carcasses before final rinse	Zero tolerance for visible fecal, milk and ingesta contamination.	FSIS Directive 6420.1  To access on the internet, go to: <a href="http://www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/FSISDir6420-1.pdf">http://www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/FSISDir6420-1.pdf</a>
Pre-Rigor (hot) Deboning	B- <i>Salmonella</i> , <i>Listeria monocytogenes</i> , <i>Aeromonas hydrophilia</i> , and <i>Campylobacter</i> survival and/or growth	Hot boned and vacuum packaged (40-45 minutes post mortem) and stored at 34°F (1°C)	Hot processed and packaged meat supported survival and growth (no log change to 2.5 log units of growth) of <i>Salmonella</i> , <i>L. monocytogenes</i> , <i>Aeromonas hydrophilia</i> , and <i>Campylobacter</i> despite immediate storage at refrigerated temperatures. A hazard is likely to occur if fecal contamination is not removed prior to storage.	Van Laack, R.L.J.M., J.L Johnson, C.J.N.M. van der Palen, F.J.M. Smulders, and J.M.A. Snijders. 1993. Survival of pathogenic bacteria on pork loins as influenced by hot processing and packaging. Journal of Food Protection. 56 (10) 847-851.
Chilling	B – <i>E. coli</i> survival	Pass pork carcasses through a freezing tunnel at – 4°F (-20°C) for 45 to 60 minutes prior to entering a conventional chiller (32 to 36°F (0 to 2°C))	The entire carcass (deep temperature) is reduced to below 45°F (7°C) during the chilling process and a bacterial hazard from <i>E. coli</i> is not likely to occur.	Gill, C.O., and T. Jones. 1992. Assessment of the hygienic efficiencies of two commercial processes for cooling pig carcasses. Food Microbiology. 9 (4) 335-343.



Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chilling	B – <i>E. coli</i> survival	Pork carcasses are immediately placed into a conventional chiller at 30 to 36°F (-1 to 2°C) then sprayed with 41°F (5°C) water for 20 seconds over 10 minutes.	The surface of the carcass is reduced to below 45°F (7°C) during the chilling process, however the internal temperature (deep temperature) is only reduced to approximately 50°F (10°C). Thus a bacterial hazard from <i>E. coli</i> is likely to occur.	Gill and Jones 1992 cont'



# **Poultry Slaughter Process**



# Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cloacal plugging	B – <i>Campylobacter</i> spp. contamination	Cloacally plugging chickens prior to electrocution	Cloacal plugging prior to electrocution resulted in 2.5 to 3 log units less <i>Campylobacter</i> spp.	Musgrove, M.T., J.A. Cason, D.L. Fletcher, N.J. Stern, N.A. Cox, J.S. Bailey. 1997. Effect of cloacal plugging on microbial recovery from partially processed broilers. Poultry Science. 76 (3) 530-533.
Scalding	B – <i>Salmonella typhimurium</i> attachment to skin	Scalding chicken carcasses 1 to 2 minutes at 126°F (52°C), 133°F (56°C), or 140°F (60°C)	<i>Salmonella typhimurium</i> attached to chicken skin after scalding at 140°F (60°C) for 1 to 2 minutes were 1.1 to 1.3 log units higher than scalding at 126°F (52°C), or 133°F (56°C).	Kim, J.W., M.F. Slavik, C.L. Griffis, and J.T. Walker. 1993. Attachment of <i>Salmonella typhimurium</i> to skins of chicken scalded at various temperatures. Journal of Food Protection. 56 (8) 661-665.
	B – <i>Salmonella typhimurium</i> and <i>Campylobacter jejuni</i> attachment to skin		<i>Salmonella typhimurium</i> attached to chicken skin after scalding at 140°F (60°C) for 1 to 2 minutes were 0.3 to 0.5 log units higher than scalding at 126°F (52°C), or 133°F (56°C), <i>Campylobacter jejuni</i> recovered from the 140°F (60°C) scalded carcasses were 0.7 log more than those scalded at 126°F (52°C), or 133°F (56°C).	Slavik, M.F., J.W. Kim, and J.T. Walker. 1995. Reduction of <i>Salmonella</i> and <i>Campylobacter</i> on chicken carcasses by changing scalding temperature. Journal of Food Protection. 58 (6) 689-691.



Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Scalding	B – <i>Salmonella typhimurium</i> and <i>Campylobacter jejuni</i> attachment to skin	Scald chicken carcasses 5 minutes at 122°F (50°C), 131°F (55°C), or 140°F (60°C)	When scalding at 122°F (50°C), there was no log change in <i>S. typhimurium</i> , and a 1.5 log decrease in <i>C. jejuni</i> . At 131°F (55°C), <i>S. typhimurium</i> was reduced 1 log unit, and <i>C. jejuni</i> was reduced 3 log units. At 140°F (60°C), both <i>S. typhimurium</i> and <i>C. jejuni</i> were reduced 2 log units.	Yang, H., Y. Li, M.G. Johnson. 2001. Survival and death of <i>Salmonella typhimurium</i> and <i>Campylobacter jejuni</i> in processing water and on chicken skin during poultry scalding and chilling. Journal of Food Protection. 64 (6) 770-776.
		Effectiveness of scald water additives at 129 to 133°F (54 to 56°C) for 2 minutes	Positive incidence of salmonellae is reduced from 67% positive samples to 8% positive samples with 0.5% and 1% H <sub>2</sub> O <sub>2</sub> . 1% lactic or acetic acids, NaOH (ph=10.5) and 100 ppm Chlorine had little to no effect on percent positive samples.	Izat, A.L., M. Colberg, M.H. Adams, M.A. Reiber, and P.W. Waldroup. 1989. Production and processing studies to reduce the incidence of salmonellae on commercial broilers. Journal of Food Protection. 52 (9) 670-673.
		Scalding broiler carcasses for 2 minutes at 122°F (50°C), with addition to scald water of 0.5% to 6% acetic acid	<i>Salmonella typhimurium</i> was reduced less than 1.2 log units with 0.5% and 1% and was reduced 1.5 to 2 log units with 2% to 6% acid.	Tamblyn, K.C., and D.E. Conner. 1997. Bactericidal activity of organic acids against <i>Salmonella typhimurium</i> attached to broiler chicken skin. Journal of Food Protection. 60 (6) 629-633.
		Scalding broiler carcasses for 2 minutes at 122°F (50°C), with addition to scald water of 0.5% to 6% citric acid	<i>Salmonella typhimurium</i> was reduced less than 1 log unit with 0.5% and was reduced 1.5 to 2 log units with 1% to 6% acid.	



Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Scalding	B – Salmonellae contamination	Scalding broiler carcasses for 2 minutes at 122°F (50°C), with addition to scald water of 0.5% to 6% lactic acid	<i>Salmonella typhimurium</i> was reduced less than 1 log unit with 0.5% and was reduced 1.5 to 3 log units with 1% to 6% acid.	Tamblyn and Conner 1997 cont'
		Scalding broiler carcasses for 2 minutes at 122°F (50°C), with addition to scald water of 0.5% to 6% malic acid	<i>Salmonella typhimurium</i> was reduced less than 1 log unit with 0.5% and was reduced 1 to 2 log units with 1% to 6% acid.	
		Scalding broiler carcasses for 2 minutes at 122°F (50°C), with addition to scald water of 0.5% to 6% mandelic acid	<i>Salmonella typhimurium</i> was reduced less than 1 log unit with 0.5% and 1% and was reduced 1 to 2 log units with 2% to 6% acid.	
		Scalding broiler carcasses for 2 minutes at 122°F (50°C), with addition to scald water of 0.5% to 6% propionic acid	<i>Salmonella typhimurium</i> was reduced less than 1.3 log units with up to 6% acid.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Scalding	B – Salmonellae contamination	Scalding broiler carcasses for 2 minutes at 122°F (50°C), with addition to scald water of 0.5% to 6% tartaric acid	<i>Salmonella typhimurium</i> was reduced 0.5 to 1.5 log units with 0.5% to 2% and was reduced 1 to 2 log units with 4% and 6% acid.	Tamblyn and Conner 1997 cont'
		Scald broiler carcasses for 2 minutes at 122°F (50°C), with addition to scald water of 0.5% or 1% acetic, citric, lactic, malic or tartaric acids, plus, transdermal synergists of 2% ethanol, 125 ppm sodium lauryl sulfate, 15% dimethyl sulfoxide, or 100 ppm sorbitan monolaurate	<i>Salmonella typhimurium</i> showed less than 1.5 log reduction with all scald water treatments that contained acids and synergists, except for 0.5% citric acid, with 100 ppm sorbitan monolaurate; malic acid (both concentrations) with 125 ppm sodium lauryl sulfate showed a 2 log reduction and tartaric acid (both concentrations) with 100 ppm sorbitan monolaurate showed a 2.75 log decrease.	Tamblyn, K.C., and D.E. Conner. 1997. Bactericidal activity of organic acids in combination with transdermal compounds against <i>Salmonella typhimurium</i> attached to broiler skin. Food Microbiology. 14 (5) 477-484.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Defeathering	B – <i>Salmonella</i> cross contamination	Defeathering turkey carcasses conventionally (scalded in a triple pass tank for 1.3 minutes at 137.5°F (58.6°C)), Kosher (cold scalded 1 minute at 45°F (7°C)), or steam sprayed for 1.6 minutes with a combination of 140°F (60°C) water and steam.	There was no significant difference in positive samples of <i>Salmonella</i> between the three types of defeathering.	Clouser, C.S., S.J. Knabel, M.G. Mast, and S. Doores. 1995. Effect of type of defeathering system on <i>Salmonella</i> cross-contamination during commercial processing. Poultry Science. 74 (4) 732-741.
	B – <i>Salmonella</i> and <i>Listeria monocytogenes</i> cross contamination	Defeathering turkey carcasses conventionally (scalded in a triple pass tank for 1.3 minutes at 137.5°F (58.6°C)), Kosher (cold scalded 1 minute at 45°F (7°C)), or steam sprayed for 1.6 minutes with a combination of 140°F (60°C) water and steam.	There was no significant difference between Kosher picking and the steam spray method, however incidence of <i>Salmonella</i> increased 50% with conventional picking. There was no <i>Listeria monocytogenes</i> detected associated with the picking process, however there was a significant increase in positive samples from those Kosher picked in the chilling process.	Clouser, C.S., S. Doores, M.G. Mast, and S.J. Knabel. 1995. The role of defeathering in the contamination of turkey skin by <i>Salmonella</i> species and <i>Listeria monocytogenes</i> . Poultry Science. 74 (4) 723-731.



# Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Pre-evisceration wash	B – <i>Salmonella</i> , <i>Staphylococcus</i> , and <i>Clostridium</i> spp. contamination	Spray washing defeathered, uneviscerated chicken carcasses with tap water at 50 psi for 2.5 minutes	Spray washing after defeathering but before evisceration had no significant effect on the incidence of <i>Salmonella</i> , <i>Staphylococcus</i> , and <i>Clostridium</i> spp.	Lillard, H.S., D. Hamm, J.E. Thompson. 1984. Effect of reduced processing on recovery of foodborne pathogens from hot-boned broiler meat and skin. Journal of Food Protection. 47 (3) 209-212.
Viscera removal	Cross-contamination by automatic viscera removal equipment	Wash automatic viscera removal equipment probe with plastic bristled brush rotating at 1700 rpm and sprayed rinsed with chlorinated water	The risk of cross-contamination is eliminated with this wash process between each carcass.	Thayer, S.G., and J.L. Walsh. 1993. Evaluation of cross-contamination on automatic viscera removal equipment. Poultry Science. 72 (4) 741-746.
House inspection/trim	B – Pathogen contamination from feces	Final trim of carcasses before final rinse	Zero tolerance for visible fecal contamination.	Directive 6150.1, for internet access, go to:  <a href="http://www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/FSISDir6150-1.pdf">http://www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/FSISDir6150-1.pdf</a>  MPI Regulations, Sec. 381.65(e), for internet access, go to:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html</a>



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Reprocessing	B – Contamination from <i>E. coli</i> and <i>Salmonella</i>	Reprocessing prior to chilling according to USDA regulations	No overall log difference was found between initially processed and reprocessed chickens before chilling carcasses.	Blankenship, L.C., J.S. Bailey, N.A. Cox, M.T. Musgrove, M.E. Berrang, R.L. Wilson, M.J. Rose, and S.K. Dua. 1993. Broiler carcass reprocessing, a further evaluation. <i>Journal of Food Protection</i> . 56 (11) 983-985.
Dip/Rinse	B – <i>Salmonella</i> contamination	Spray chicken carcasses with 0.85% NaCl at 207, 345, or 827 kPa water for 30 or 90 seconds	There was less than 0.25 log reduction of <i>S. typhimurium</i> when sprayed up to 90 seconds and up to 827 kPa pressure.	Li, Y., M.F. Slavik, J.T. Walker, H. Xiong. 1997. Pre-chill spray of chicken carcasses to reduce <i>Salmonella typhimurium</i> . <i>Journal of Food Science</i> . 62 (3) 605-607.
		Spray chicken carcasses with 5% trisodium phosphate (TSP) at 207, 345, or 827 kPa water for 30 or 90 seconds	When sprayed for 30 seconds (any pressure) there was less than 1 log reduction of <i>S. typhimurium</i> . When sprayed for 90 seconds there was approximately 1.5 log reduction of <i>S. typhimurium</i> .	
		Spray chicken carcasses with 10% trisodium phosphate (TSP) at 207, 345, or 827 kPa water for 30 or 90 seconds	When sprayed for 30 seconds (any pressure) there was 1.5 to 2 log reduction of <i>S. typhimurium</i> . When sprayed for 90 seconds there was 1.5 to 4 log reduction of <i>S. typhimurium</i> .	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Dip/Rinse	B – <i>Salmonella</i> contamination	Spray chicken carcasses with 5% sodium bisulfate (SBS) at 207, 345, or 827 kPa water for 30 or 90 seconds	When sprayed for 30 seconds (any pressure) there was less than 1 log reduction of <i>S. typhimurium</i> . When sprayed for 90 seconds there was approximately 1.25 log reduction of <i>S. typhimurium</i> .	Li et al. 1997 cont'
		Spray chicken carcasses with 10% sodium bisulfate (SBS) at 207, 345, or 827 kPa water for 30 or 90 seconds	When sprayed for 30 seconds (any pressure) there was 1.2 to 1.5 log reduction of <i>S. typhimurium</i> . When sprayed for 90 seconds there was 2.3 to 2.6 log reduction of <i>S. typhimurium</i> .	
		Spray chicken carcasses with 1% cetylpyridinium chloride (CPC) at 207, 345, or 827 kPa water for 30 or 90 seconds	When sprayed for 30 seconds (any pressure) there was less than 1 log reduction of <i>S. typhimurium</i> . When sprayed for 90 seconds there was less than 1.5 log reduction of <i>S. typhimurium</i> .	
		Spray chicken carcasses with 1% lactic acids at 207, 345, or 827 kPa water for 30 seconds	When sprayed for 30 seconds (any pressure) there was less than 1 log reduction of <i>S. typhimurium</i> .	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Dip/Rinse	B – <i>Salmonella</i> contamination	Dip chicken carcasses in 10% solution of trisodium phosphate (TSP), at 50°F (10°C), or 122°F (50°C) for 15 seconds	Both control (no TSP) and 10% TSP dip (at both temperatures) decreased the incidence of <i>Salmonella</i> 1.6-1.8 log units (27-46%). Overall the 122°F (50°C) dip showed a greater log reduction by 0.4 units than at 50°F (10°C).	Kim, J.W., M.F. Slavik, M.D. Pharr, D.P. Raben, C.M. Lobsinger, and S. Tsai. 1994. Reduction of <i>Salmonella</i> on post-chill chicken carcasses by trisodium phosphate (Na <sub>3</sub> PO <sub>4</sub> ) treatment. <i>Journal of Food Safety</i> . 14 (1) 9-17.
		Dip broiler carcasses in 2% lactic acid, 99°F (37°C) for 2 minutes	Salmonellae incidence decreased from 100% to 0% positive samples when carcasses were dipped in 2% lactic acid at 99°F (37°C). 40°F (4°C) dips and less than 2 minutes in the 99°F (37°C) dip had little to no effect on the incidence of salmonellae.	Izat, A.L., M. Colberg, M.H. Adams, M.A. Reiber, and P.W. Waldroup. 1989. Production and processing studies to reduce the incidence of salmonellae on commercial broilers. <i>Journal of Food Protection</i> . 52 (9) 670-673.
		Dipping broiler carcasses for 15 seconds at 73°F (23°C), into dip water containing 0.5% to 6% acetic acid	There was little to no effect of the acid dips at any concentration on <i>Salmonella typhimurium</i> .	Tamblyn, K.C., and D.E. Conner. 1997. Bactericidal activity of organic acids against <i>Salmonella typhimurium</i> attached to broiler chicken skin. <i>Journal of Food Protection</i> . 60 (6) 629-633.
		Dipping broiler carcasses for 15 seconds at 73°F (23°C), into dip water containing 0.5% to 6% citric acid	There was little to no effect of the acid dips at any concentration on <i>Salmonella typhimurium</i> .	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Dip/Rinse	B – <i>Salmonella</i> contamination	Dipping broiler carcasses for 15 seconds at 73°F (23°C), into dip water containing 0.5% to 6% lactic acid	There was less than 0.5 log reduction with up to 4% acid. 6% acid showed a 0.75 to 1.2 log reduction.	Tamblyn and Connor 1997 cont'
		Dipping broiler carcasses for 15 seconds at 73°F (23°C), into dip water containing 0.5% to 6% malic acid	There was little to no effect of the acid dips at any concentration on <i>Salmonella typhimurium</i> .	
		Dipping broiler carcasses for 15 seconds at 73°F (23°C), into dip water containing 0.5% to 6% mandelic acid	4% acid or less showed less than 1 log reduction. 6% acid showed a 0.75 to 2 log reduction.	
		Dipping broiler carcasses for 15 seconds at 73°F (23°C), into dip water containing 0.5% to 6% propionic acid	There was little to no effect of the acid dips on <i>Salmonella typhimurium</i> up to 4%. At 6% there was a 0.5 to 1.65 log reduction.	



Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Dip/Rinse	B – <i>Salmonella</i> contamination	Dipping broiler carcasses for 15 seconds at 73°F (23°C), into dip water containing 0.5% to 6% tartaric acid	There was little to no effect of the acid dips at any concentration on <i>Salmonella typhimurium</i> .	Tamblyn and Connor 1997 cont'
		Dipping broiler carcasses for 15 seconds at 73°F (23°C), into dip water containing 0.5% or 1% acetic, citric, lactic, malic or tartaric acids plus transdermal synergists of 2% ethanol, 125 ppm sodium lauryl sulfate, 15% dimethyl sulfoxide, or 100 ppm sorbitan monolaurate	<i>Salmonella typhimurium</i> showed less than 0.5 log reduction with all acid and synergists except 1% acetic acid with 125 ppm sodium lauryl sulfate, which showed between 0.5 and 1 log reduction.	Tamblyn, K.C., and D.E. Conner. 1997. Bactericidal activity of organic acids in combination with transdermal compounds against <i>Salmonella typhimurium</i> attached to broiler skin. Food Microbiology. 14 (5) 477-484.
Dip and Chill	B – <i>Salmonella</i> contamination	Rinse turkey carcasses in 200 ppm chlorine for 10 seconds then chilled for 4 hours in 0.5% Slow release chlorine dioxide (SRCD)	No positive samples of <i>Salmonella</i> (65 to 75% positive pre rinse).	Villarreal, M.E., R.C. Baker, and J.M. Regenstein. 1990. The incidence of <i>Salmonella</i> on poultry carcasses following the use of slow release chlorine dioxide (Alcide). Journal of Food Protection. 53 (6) 465-467.



Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation								
Dip and Chill	B – <i>Salmonella</i> contamination	Dip turkey carcasses in 4.5% SRCD for 20 seconds, pre chill	No positive samples of <i>Salmonella</i> (65 to 75% positive pre rinse).	Villarreak et al. 1990 cont'								
		Dip turkey carcasses in 4.5% SRCD for 20 seconds and chilled for 4 hours in 0.5% SRCD	No positive samples of <i>Salmonella</i> (65 to 75% positive pre rinse).									
		Dip turkey carcasses in 4.5% SRCD for 20 seconds and chilled for 4 hours in iced water	0 to 10% positive <i>Salmonella</i> samples (65 to 75% positive pre rinse).									
Chill carcasses	B – Pathogen growth	Chilling poultry carcasses after slaughter	Poultry carcasses shall be chilled to 40°F (4°C) or lower within the following specified times: <table><tr><td>Time (hours)</td><td>Weight of carcass</td></tr><tr><td>4</td><td>&lt; 4 pounds</td></tr><tr><td>6</td><td>4-8 pounds</td></tr><tr><td>8</td><td>&gt; 8 pounds</td></tr></table>	Time (hours)	Weight of carcass	4	< 4 pounds	6	4-8 pounds	8	> 8 pounds	MPI Regulations, Sec. 381.66(b)(2)  Access on internet at:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html</a>
Time (hours)	Weight of carcass											
4	< 4 pounds											
6	4-8 pounds											
8	> 8 pounds											



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chill carcasses	B – Growth of <i>Campylobacter jejuni</i> in chill water	Treat chill water containing 0.1% NaCl (pH 7) with 10mA/cm <sup>2</sup> and 1 kHz pulsed electrical current	<i>Campylobacter jejuni</i> decreased 2 to 3 log units in 20 minutes.	Li, Y., J.T. Walker, M.F. Slavik, and H. Wang. 1995. Electrical treatment of poultry chiller water to destroy <i>Campylobacter jejuni</i> . Journal of Food Protection. 58 (12) 1330-1334.
		Treat chill water containing 0.2% NaCl (pH 7) with 10mA/cm <sup>2</sup> and 1 kHz pulsed electrical current	<i>Campylobacter jejuni</i> decreased 2 to 4 log units in 20 minutes.	
		Treat chill water containing 0.3% NaCl (pH 7) with 10mA/cm <sup>2</sup> and 1 kHz pulsed electrical current	<i>Campylobacter jejuni</i> decreased 3 log units in 15 minutes.	
		Treat chill water containing 0.1% trisodium phosphate (pH 11 to 12) with 10mA/cm <sup>2</sup> and 1 kHz pulsed electrical current	<i>Campylobacter jejuni</i> decreased 1 log unit in 20 minutes.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chill carcasses	B – Growth of <i>Campylobacter jejuni</i> in chill water	Treat chill water containing 0.2% trisodium phosphate (pH 11 to 12) with 10mA/cm <sup>2</sup> and 1 kHz pulsed electrical current	<i>Campylobacter jejuni</i> decreased 2 to 4 log units in 20 minutes.	Li et al. 1995 cont'
		Treat chill water containing 0.3% trisodium phosphate (pH 11 to 12) with 10mA/cm <sup>2</sup> and 1 kHz pulsed electrical current	<i>Campylobacter jejuni</i> decreased 1 to 3 log units in 3 minutes.	
	B – Survival of <i>Salmonella typhimurium</i> , and <i>Campylobacter jejuni</i>	Chill chicken carcasses in water containing up to 50 ppm chlorine	The amount of chlorine did not change the log count of <i>S. typhimurium</i> or <i>C. jejuni</i> in chiller water tested fresh to 8 hours.	Yang, H., Y. Li, M.G. Johnson. 2001. Survival and death of <i>Salmonella typhimurium</i> and <i>Campylobacter jejuni</i> in processing water and on chicken skin during poultry scalding and chilling. Journal of Food Protection. 64 (6) 770-776.
	B – <i>Salmonella</i> growth	Times, meat pH, and temperatures to reach level of food safety concern	Insert poultry temperature, pH and % sodium chloride into model to determine <i>Salmonella</i> growth.	ARS <i>Salmonella</i> growth model:  <a href="http://www.arserrc.gov/mfs/PATHOGEN.HTM">http://www.arserrc.gov/mfs/PATHOGEN.HTM</a>



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chill carcasses	B – <i>Salmonella</i> contamination	Chilling broiler carcasses with addition of 0.6% acetic acid to chill water	Use of 0.6% acetic acid, when combined with air or paddle agitation, reduced <i>Salmonella</i> incidence by 30%, and reduced Enterobacteriaceae by 1 log or less.	Dickens, J. A. and A. D. Whittemore. 1995. The effects of Extended Chilling Times with Acetic Acid on the Temperature and Microbiological Quality of Processed Poultry Carcasses. Poultry Sci. 74:1044-1048.
		Chilling broiler carcasses for 1 hour at 34 to 35°F (1.1 to 1.7°C), in chill water containing 0.5% to 1% H <sub>2</sub> O <sub>2</sub> , 1% lactic acid, or 100 ppm Chlorine	Salmonellae incidence is reduced 50 to 66% with the addition of any one of these additives to the chill water.	Izat, A.L., M. Colberg, M.H. Adams, M.A. Reiber, and P.W. Waldroup. 1989. Production and processing studies to reduce the incidence of salmonellae on commercial broilers. Journal of Food Protection. 52 (9) 670-673.
		Chilling broiler carcasses for 1 hour at 32°F (0°C), in chill water containing 0.5% to 6% acetic acid	<i>Salmonella typhimurium</i> was reduced less than 0.7 log units with up to 6% acetic acid.	Tamblyn, K.C., and D.E. Conner. 1997. Bactericidal activity of organic acids against <i>Salmonella typhimurium</i> attached to broiler chicken skin. Journal of Food Protection. 60 (6) 629-633.
		Chilling broiler carcasses for 1 hour at 32°F (0°C), in chill water containing 0.5% to 6% citric acid	<i>Salmonella typhimurium</i> was reduced less than 0.5 log reduction at 0.5% to 2% citric acid. At 4% citric acid the reduction was 1 to 2 log units and at 6% the reduction was 1.5 to 2 log units.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chill carcasses	B – <i>Salmonella</i> contamination	Chilling broiler carcasses for 1 hour at 32°F (0°C), in chill water containing 0.5% to 6% lactic acid	<i>Salmonella typhimurium</i> was reduced less than 1 log reduction at 0.5% to 2% lactic acid. At 4% lactic acid the reduction was 0.75 to 1.5 log units and at 6% the reduction was 2 to 2.25 log units.	Tamblyn and Connor 1997 cont'
		Chilling broiler carcasses for 1 hour at 32°F (0°C), in chill water containing 0.5% to 6% malic acid	<i>Salmonella typhimurium</i> was reduced less than 0.5 log reduction at 0.5% and 1% malic acid. At 2% the reduction was 1.5 log units, at 4% and 6% malic acid the reduction was 2 to 2.75 log units.	
		Chilling broiler carcasses for 1 hour at 32°F (0°C), in chill water containing 0.5% to 6% mandelic acid	<i>Salmonella typhimurium</i> was reduced less than 0.5 log reduction at 0.5% to 2% mandelic acid. At 4% and 6% acid the reduction was 2 log units.	
		Chilling broiler carcasses for 1 hour at 32°F (0°C), in chill water containing 0.5% to 6% propionic acid	<i>Salmonella typhimurium</i> was reduced less than 1 log reduction at 0.5% and 1% propionic acid. At 2% acid the reduction was 1 to 1.5 log units, at 4% acid the reduction was 1 to 2.25 log units and at 6% the reduction was 1.75 to 2.25 log units.	
		Chilling broiler carcasses for 1 hour at 32°F (0°C), in chill water containing 0.5% to 6% tartaric acid	<i>Salmonella typhimurium</i> was reduced less than 0.5 log reduction at 0.5% to 4% tartaric acid. At 6% acid the reduction was 1.5 log units.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chill carcasses	B – <i>Salmonella</i> contamination	Chilling broiler carcasses for 1 hour at 32°F (0°C), in chill water containing 0.5% or 1% acetic, citric, lactic, malic or tartaric acids plus transdermal synergists of 2% ethanol, 125 ppm sodium lauryl sulfate, 15% dimethyl sulfoxide, or 100 ppm sorbitan monolaurate	<i>Salmonella typhimurium</i> showed less than 0.5 log reduction with all acid and synergists except 1% lactic or 1% acetic acid with 125 ppm sodium lauryl sulfate, and 1% malic acid showed between 0.5 and 1 log reduction.	Tamblyn, K.C., and D.E. Conner. 1997. Bactericidal activity of organic acids in combination with transdermal compounds against <i>Salmonella typhimurium</i> attached to broiler skin. Food Microbiology. 14 (5) 477-484.
		Fresh water input at a rate of 0.25 to 0.5 gallons per carcass with 0 to 50 ppm chlorine	There is no significant effect detected when using a higher rate of fresh water input. There was less cross-contamination detected with the use of 50 ppm chlorine than with no chlorine, but the cross contamination was not eliminated. Chlorine decreases rapidly in the chilling water because of interaction with organic matter.	Thompson, J.E., J.S. Bailey, N.A. Cox, D.A. Posey, and M.O. Carson. 1979. <i>Salmonella</i> on broiler carcasses as affected by fresh water input rate and chlorination of chiller water. Journal of Food Protection. 42 (12) 954-955.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Post Chill Dip/Spray	B – Salmonellae contamination	Dipping broiler carcasses at 40°F (4°C) for 1 to 10 minutes in 1% lactic acid, 0.5% or 1% H <sub>2</sub> O <sub>2</sub>	Salmonellae incidences decreased with these additives in the dips from 100% positive samples to 33 to 17% positive samples.	Izat, A.L., M. Colberg, M.H. Adams, M.A. Reiber, and P.W. Waldroup. 1989. Production and processing studies to reduce the incidence of salmonellae on commercial broilers. Journal of Food Protection. 52 (9) 670-673.
		Dipping broiler carcasses at 40°F (4°C) for 30 seconds in 20% Ethanol	This treatment had little to no effect on the incidences of positive salmonellae samples.	
		Spraying chilled broiler carcasses for 2 minutes with 2% or 5% lactic acid		
		Spraying chilled broiler carcasses with water containing up to 50 ppm chlorine	No significant change was detected in log counts of psychrophiles or total aerobes or the number of positive samples of salmonellae between 0 and 50 ppm chlorine.	
	B – <i>Campylobacter</i> spp. contamination	Dip chilled carcasses for 15 seconds in 122°F (50°C) 10% trisodium phosphate	There was no immediate effect however, after 1 to 6 days there was a 1.2 to 1.5 log decrease (64%) in the positive incidence of <i>Campylobacter</i> spp.	Slavik, M.F., J.W. Kim, M.D. Pharr, D.P. Raben, S. Tsai, and C.M. Lobsinger. 1994. Effect of trisodium phosphate on <i>Campylobacter</i> attached to post-chill chicken carcasses. Journal of Food Protection. 57 (4) 324-326.



## **Raw, Not-Ground Process**

Includes: beef, pork, lamb, and poultry



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – <i>Staphylococcus aureus</i> growth	Storage at 50°F (10°C) or lower	Minimum growth temperature is 50°F (10°C).	Troller, J.A. 1976. Staphylococcal growth and enterotoxin production factors for control. Journal of Milk and Food Technology. 39: 499-503.
	B – <i>Staphylococcus aureus</i> toxin production	Storage at 50°F (10°C) or lower	Minimum toxin production temperature is a few degrees above the minimum growth temperature.	Pereira, J.L., S.P. Salsberg, and M.S. Bergdoll. 1982. Effect of temperature, pH and sodium chloride concentrations on production of staphylococcal enterotoxins A and B. Journal of Food Protection. 45: 1306-1309.
	B – <i>Yersinia enterocolitica</i> growth	Storage of vacuum packed beef or lamb at 45°F (7°C)	<i>Y. enterocolitica</i> can increase in numbers at 45°F (7°).	Hanna, M.O., D.L. Zink, Z.L. Carpenter, and C. Vanderzant. 1976. <i>Yersinia enterocolitica</i> -like organisms from vacuum packaged beef and lamb. Journal of Food Science. 41: 1254-1256.
		Storage of beef or pork (in a jar, but not retorted) at 45°F (7°)		Hanna, M.O., J.C. Stewart, D.L. Zink, Z.L. Carpenter, C. Vanderzant. 1977. Development of <i>Yersinia enterocolitica</i> on raw and cooked beef and pork at different temperatures. Journal of Food Science. 42: 1180-1184.



## Raw not-ground process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – <i>Yersinia enterocolitica</i> growth	Storage of raw pork at 44.5°F (6.9°C) for 10 days	<i>Y. enterocolitica</i> showed a 4 log increase at 44.5°F (6.9°C) in 10 days.	Food Safety and Inspection Service. Facts. 1989. Preventable foodborne illness. May. 5-14.
	B – <i>Listeria monocytogenes</i> growth	Storage of raw lamb at 38°F (4°) to 42°F (6°)	<i>Listeria monocytogenes</i> is capable of growth at these temperatures.	Palumbo, S.A. 1986. Is refrigeration enough to restrain foodborne pathogens? Journal of Food Protection. 49(12) 1003-1009.
	B – <i>Salmonella</i> growth	Storage at 44°F (6.7°C) or lower	Lowest growth temp reported in a food was 44°F (6.7°C).	Angelotti, R., M.J. Foter, and K.H. Lewis, 1961. Time-temperature effects on <i>Salmonella</i> and <i>Staphylococci</i> in foods. 1. Behavior in refrigerated foods. American Journal of Public Health. 51: 76-88.
		Storage at 41.5°F (5.3°C) or 43.2°F (6.2°C) or lower	Lowest temperature for <i>Salmonella</i> growth: 41.5°F (5.3°C) <i>S. Heidelberg</i> 43.2°F (6.2°C) <i>S. typhimurium</i>	Matches, J.R., and J. Liston. 1968. Low temperature growth of <i>Salmonella</i> . Journal of Food Science. 33: 641-645.
		Pork carcass storage at 40°F (4°C)	No change in <i>Salmonella</i> prevalence after 24 hours at 40°F (4°C).	Epling, L.K., J.A. Carpenter, and L.C. Blankenship. 1993. Prevalence of <i>Campylobacter</i> spp. and <i>Salmonella</i> spp. on pork carcasses and the reduction effected by spraying with lactic acid. Journal of Food Protection. 56 (6) 536-537.



# Raw not-ground process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – Pathogen growth	Store raw meat at 41°F (5°C) or below	FDA Food Code states: Red meat, which is a potentially hazardous food, must be stored at 41°F (5°C) or below.	2001 FDA Food Code, 3-501.16 page 63.  Access on internet at:  <a href="http://www.cfsan.fda.gov/~dms/fc01-3.html#3-5">http://www.cfsan.fda.gov/~dms/fc01-3.html#3-5</a>
Cutting	B- <i>Salmonella typhimurium</i> contamination from lymph nodes in pork carcasses and primal cuts	Cutting pork carcass cuts which contain lymph nodes such as, ham, shoulder, etc.	The lymph nodes harbor <i>Salmonella typhimurium</i> , and could be a potential biological hazard if not removed or if cut into (or incised) during slaughter or processing. Care should be taken not to cut into them. Corrective action should be implemented if they are.	Wood, R.L., and R. Rose. 1989. Distribution of persistent <i>Salmonella typhimurium</i> infection in internal organs of swine. American Journal of Veterinary Research. 50 (7) 1015-1021.
	B – <i>Clostridium</i> , <i>Bacilli</i> , and other pathogenic contamination in abscesses	Cutting into pork carcasses which contain abscesses	Laboratory experience has shown no pathogenic vegetative cells and only Clostridial and Bacillial spores, of which both remained as spores in the anaerobic condition of the abscess.	Correspondence with George Beran, D.V.M., Ph.D., Distinguished Professor; Microbiology, Immunology, Veterinary Preventative Medicine; Iowa State University.
Process poultry carcasses	B – Pathogen growth during processing	Cutting and trimming poultry meat	If poultry carcasses exceed 55°F (13°C) during processing, they must be chilled to <40°F (4°C) in 2 hours.	MPI Regulations, Sec. 381.66 (b)(2)  Access on internet at:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html</a>



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging	B – Fecal contamination pathogen survival including but not limited to <i>Campylobacter</i> , and <i>L. monocytogenes</i>	Hot boned and vacuum packaged, stored at 34°F (1°C)	Hot processed and packaged meat supported survival and growth of pathogenic fecal bacteria despite immediate storage at refrigerated temperatures. A hazard is likely to occur if fecal contamination is not removed prior to storage.	Van Laack, R.L.J.M., J.L Johnson, C.J.N.M. van der Palen, F.J.M. Smulders, and J.M.A. Snijders. 1993. Survival of pathogenic bacteria on pork loins as influenced by hot processing and packaging. Journal of Food Protection. 56 (10) 847-851.
		Chilled and vacuum packaged, stored at 34°F (1°C)	There was no appreciable effect of packaging on the growth or survival of pathogenic bacteria with vacuum packaging. A hazard is likely to occur if fecal contamination is not removed prior to storage.	
		Chilled and left unpackaged, stored at 34°F (1°C)	<i>Campylobacter</i> , <i>L. monocytogenes</i> and other pathogens will continue to survive and grow even at refrigerated temperatures. A hazard is likely to occur if fecal contamination is not removed prior to storage.	
	B – Growth of <i>Listeria monocytogenes</i>	Vacuum packaged beef strip loin pH 5.5-5.7 stored at 32°F (5.3°C)	<i>L. monocytogenes</i> showed no log change on lean meat and showed a 2 log increase on fat after 76 days.	Grau, F.H., and P.B. Vanderlinde. 1990. Growth of <i>Listeria monocytogenes</i> on vacuum-packaged beef. Journal of Food Protection. 53 (9) 739-741.
		Vacuum packaged beef strip loin pH 5.5-5.7 stored at 41.5°F (0°C)	<i>L. monocytogenes</i> showed a 2.5 log growth on lean meat and showed a 4 log increase on fat after 30 days.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging	B- <i>Salmonella</i> growth	Pork loins vacuum packaged and stored at 36°F (2°C)	<i>Salmonella</i> prevalence reduced from 0.7% to zero after 36 days of storage at 36°F (2°C).	Saide, J.J., C.L. Knipe, E.A. Murano, and G.E. Beran. 1995. Contamination of pork carcasses during slaughter, fabrication and chilled storage. Journal of Food Protection. 58 (9) 993-997.
	B – Pathogen growth	Poultry internal temperature maintained at 40°F (4°C) during storage and at 55°F (12.8°C) during processing	... Eviscerated poultry to be shipped from the establishment in packaged form shall be maintained at 40°F (4°C) or less, except that during further processing and packaging operations, the internal temperature may rise to a maximum of 55°F (12.8°C). Provided that immediately after packaging, the poultry is placed under refrigeration at a temperature that will promptly lower the internal temperature of the product to 40°F (4°C) or less, or the poultry is placed in a freezer...	FSIS poultry processing regulation: 381.66(b)  Access on the internet at:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html</a>
Acid sprays and dips	B – <i>E. coli</i> , <i>L. monocytogenes</i> , <i>Yersinia enterocolitica</i> , <i>Aeromonas hydrophilia</i> , and other <i>Enterobacteriaceae</i> inhibition	Spray beef with 36°F (2°C) 1.2% acetic or lactic acid for 120 seconds	This spray treatment inhibits the growth of bacteria on raw meat up to 9 days when stored at 36°F (2°C) (1.7 log units less than without the treatment).	Kotula, K.L., and R. Thelappurath. 1994. Microbiological and sensory attributes of retail cuts of beef treated with acetic and lactic acid solutions. Journal of food Protection. 57 (8) 665 – 670.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Acid sprays and dips	B – <i>E. coli</i> , <i>L. monocytogenes</i> , <i>Yersinia enterocolitica</i> , <i>Aeromonas hydrophilia</i> , and other <i>Enterobacteriaceae</i> inhibition	Dip pork for 2 minutes into a 3% acetic acid with 2% salt or 3% sodium ascorbate solution	A bacterial hazard is reduced by 2.0 log units when the whole muscle product is dipped, vacuum packed and stored at 36 – 40°F (2-4°C).	Mendonca, A.F., R.A. Molins, A.A. Kraft, and H.W. Walker. 1989. Microbiological, chemical and physical changes in fresh, vacuum-packaged pork treated with organic acids and salts. <i>Journal of Food Science</i> . 54 (1) 18-21.
		Dip pork for 15 seconds into a 3% lactic acid solution at 131°F (55°C) and store at 40°F (4°C) for at least 4 days	After 4 days up to 15 days of storage at 40°F (4°C) the level of <i>Yersinia enterocolitica</i> , and <i>Aeromonas hydrophilia</i> was reduced 2-3.5 log units to undetectable levels. <i>L. monocytogenes</i> was reduced about 2 log units and remained at about 4 log units for the duration.	Greer, G.G., and B.D. Dilts, 1995. Lactic-acid inhibition of the growth of spoilage bacteria and cold tolerant pathogens on pork. <i>International Journal of Food Microbiology</i> . 25 (2) 141 – 151.
	B – <i>E. coli</i> O157:H7 survival and growth	Dipped beef rounds in 2% low molecular weight polylactic acid, or 2% lactic acid with or without 400 IU/ml nisin then vacuum packaged and stored at 40°F (4°C) for 28 days	All treatments lowered <i>E. coli</i> O157:H7 less than 1.5 log units. There was no significant difference between treatments and nisin made no contribution to the antimicrobial effect of the treatments.	Mustapha, A., T. Ariyapitipun, and A.D. Clarke. 2002. Survival of <i>Escherichia Coli</i> O157:H7 on vacuum-packaged raw beef treated with polylactic acid, lactic acid and nisin. <i>Journal of Food Science</i> . 67 (1) 262-267.



# **Raw, Ground Process**

Includes: beef, pork, lamb and poultry



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cutting	B- <i>Salmonella typhimurium</i> contamination from lymph nodes in pork carcasses and primal cuts	Cutting, trimming and grinding pork carcass cuts which contain lymph nodes such as, ham, shoulder, etc.	The lymph nodes harbor <i>Salmonella typhimurium</i> , and could be a potential biological hazard if not removed or if cut into (or incised) during slaughter or processing. Care should be taken not to cut into them. Corrective action should be implemented if they are.	Wood, R.L., and R. Rose. 1989. Distribution of persistent <i>Salmonella typhimurium</i> infection in internal organs of swine. American Journal of Veterinary Research. 50 (7) 1015-1021.
	B – <i>Clostridium</i> , <i>Bacilli</i> , and other pathogenic contamination in abscesses	Cutting into pork carcasses which contain abscesses	Laboratory experience has shown no pathogenic vegetative cells and only Clostridial and Bacillial spores, of which both remained as spores in the anaerobic condition of the abscess.	Correspondence with George Beran, D.V.M, Ph.D., Distinguished Professor; Microbiology, Immunology, Veterinary Preventative Medicine; Iowa State University.
Nitrite addition	C and B – Excessive nitrite level in product	Addition of preblended cure including sodium nitrite	“[If] using sodium nitrite diluted [to 6.25% by weight] with sodium chloride, which is received from the manufacturer with a continuing letter of guarantee, then acute nitrite toxicity is not a problem.” (due to self-limiting, high, salt concentration)	Borchert, L.L., and R. G. Cassens. 1998. Chemical hazard analysis for sodium nitrite in meat curing. American Meat Institute Foundation Paper.
		Addition of pure sodium nitrite	“Extreme caution must be exercised if pure sodium nitrite is used.” “The conservative estimate for a lethal dose in humans is 14 mg/kg, meaning the dose would be 1 g [(0.0022 lb)] for a 70 kg [(154 lb)] adult and 0.2 g [(8.8x10 <sup>-5</sup> lb)] for a 15 kg [(33 lb)] child.”	For internet access, go to: <a href="http://www.ag.ohio-state.edu/~meatsci/borca2.htm">http://www.ag.ohio-state.edu/~meatsci/borca2.htm</a>



# Raw, Ground Process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Nitrite addition	C and B – Excessive nitrite level in product	Addition of sodium nitrite	Sodium nitrite can be added up to 200 parts per million (or an equivalent of potassium nitrite) in the final product except in bacon where it can be added up to 120 ppm ingoing.	CFR 318.71  To access on the internet:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301</a>
Phosphate addition	B – Growth of <i>L. monocytogenes</i> , <i>S. typhimurium</i> , and <i>E. coli</i> O157:H7	Addition of 0.5% phosphate blend to ground beef or pork	There is minimal or no effect of the phosphate addition on the growth of <i>L. monocytogenes</i> , <i>S. typhimurium</i> , and <i>E. coli</i> O157:H7.	Flores, L.M., S.S. Sumner, D.L. Peters, and R. Mandigo. 1996. Evaluation of a phosphate to control pathogen growth in fresh and processed meat products. Journal of Food Protection. 59 (4) 356-359.
Process poultry carcasses	B – Pathogen growth during processing	Cutting, trimming and grinding poultry meat	If poultry carcasses exceed 55°F (13°C) during processing, they must be chilled to <40°F (4°C) in 2 hours.	MPI Regulations, Sec. 381.66 (b)(2)  Access on internet at:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html</a>
Storage	B – <i>S. typhimurium</i> growth	Times and temperatures to reach level of food safety concern	You enter the time and temperatures between 46°F (8°C) and 118°F (48°C). This spreadsheet will provide you with lag time growth rate and overall log growth for the parameters set.	Poultry Food Access Risk Model (FARM), on ARS Website:  <a href="http://www.arserrc.gov/mfs/Pfarmrsk.htm#pre">http://www.arserrc.gov/mfs/Pfarmrsk.htm#pre</a>



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – <i>Listeria monocytogenes</i> contamination and growth	pH of uncooked bratwurst 5.35-6.45 stored at 40°F (4.4°C)	A hazard is likely if contaminated ( $6.1 \times 10^2$ inoculation) with <i>Listeria monocytogenes</i> . It will continue to grow (4 log increase over 6 weeks) and create a biological risk.	Glass, K.A., and M.P. Doyle. 1989. Fate of <i>Listeria monocytogenes</i> in processed meat products during refrigerated storage. Applied and Environmental Microbiology. 55 (6) 1565-1569.
	B – <i>Staphylococcus aureus</i> growth	Storage at 50°F (10°C) or lower	Minimum <i>Staphylococcus aureus</i> growth temperature is 50°F (10°C).	Troller, J.A. 1976. Staphylococcal growth and enterotoxin production factors for control. Journal of Milk and Food Technology. 39: 499-503.
	B – <i>Staphylococcus aureus</i> toxin production	Storage at 50°F (10°C) or lower	Minimum toxin production temperature is a few degrees above the minimum growth temperature.	Pereira, J.L., S.P. Salsberg, and M.S. Bergdoll. 1982. Effect of temperature, pH and sodium chloride concentrations on production of staphylococcal enterotoxins A and B. Journal of Food Protection. 45: 1306-1309.
	B – <i>Yersinia enterocolitica</i> growth	Storage of raw pork at 44.5°F (6.9°C) for 10 days	<i>Y. enterocolitica</i> showed a 4 log increase at 44.5°F (6.9°C) in 10 days.	Food Safety and Inspection Service. Facts. 1989. Preventable foodborne illness. May. 5-14.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – <i>Salmonella</i> growth	Storage at 44°F (6.7°C) or lower	Lowest <i>Salmonella</i> growth temperature reported in a food was 44°F (6.7°C).	Angelotti, R., M.J. Foter, and K.H. Lewis, 1961. Time-temperature effects on <i>Salmonella</i> and <i>Staphylococci</i> in foods. 1. Behavior in refrigerated foods. American Journal of Public Health. 51: 76-88.
		Storage at 41.5°F (5.3°C) or 43.2°F (6.2°C) or lower	Lowest temperature for growth: 41.5°F (5.3°C) <i>S. Heildelberg</i> 43.2°F (6.2°C) <i>S. typhimurium</i>	Matches, J.R., and J. Liston. 1968. Low temperature growth of <i>Salmonella</i> . Journal of Food Science. 33: 641-645.
		Vacuum packaged ground beef storage	Lowest temperature for growth of <i>Salmonella</i> on vacuum packaged ground beef is 50°F (10°C).	Ayres, J.C. 1978. <i>Salmonella</i> in meat products. In proceedings from the 31 <sup>st</sup> annual Reciprocal Meats Conference. 148-155.
	B – Survival of <i>E. coli</i> O157:H7	Storage of ground beef at -4°F (-20°C)	There was no log change in <i>E. coli</i> O157:H7 when stored at -4°F (-20°C) for 0 to 9 months.	Doyle, M.P., J.L. Schoeni. 1984. Survival and growth characteristics of <i>Escherichia coli</i> associated with hemorrhagic colitis. Applied and Environmental Microbiology. 10, 855-856.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – Survival and growth of <i>E. coli</i> O157:H7	Vacuum packaged ground beef, and fresh pork sausage stored at 40°F (4°C) for 7 days	At 40°F (4°C) there was approximately 0.7 log reduction in the number of <i>E. coli</i> O157:H7 organisms.	Flores, L.M., S.S. Sumner, D.L. Peters, and R. Mandigo. 1996. Evaluation of a phosphate to control pathogen growth in fresh and processed meat products. Journal of Food Protection. 59 (4) 356-359.
		Vacuum packaged ground beef, and fresh pork sausage stored at 54°F (12°C) for 7 days	At 54°F (12°C) <i>E. coli</i> O157:H7 grew 1.5-2 log units in pork and 5-6 log units in beef in 7 days.	
		Vacuum packaged ground beef, and fresh pork sausage stored at 68°F (20°C) for 24 hours	At 68°F (20°C) <i>E. coli</i> O157:H7 grew 1.5-2 log units in pork and 3.5-4 log units in beef in 24 hours.	
	B – Growth of <i>L. monocytogenes</i> and <i>S. typhimurium</i>	Vacuum packaged ground beef, and fresh pork sausage stored at 40°F (4°C) for 7 days	At 40°F (4°C) there was little (less than 0.5 log reduction) or no growth of <i>L. monocytogenes</i> and <i>S. typhimurium</i> .	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – Growth of <i>L. monocytogenes</i> during refrigeration	Storage of ground beef (pH 6.2, and 15 or 38% fat) at 40°F (4°C)	<i>L. monocytogenes</i> showed a generation time of 1.2 days for 15% fat and 1.45 days for 38% fat.	Rosso, L., S. Bajard, J.P. Flandrois, C. Lahellec, J. Fournaud, and P. Veit. 1996. Differential growth of <i>Listeria monocytogenes</i> at 4 and 8°C: Consequences for the shelf life of chilled products. Journal of Food Protection. 59 (9) 944-949.
		Storage of minced beef (pH 6.2, and 15 or 38% fat) at 42°F (6°C)	<i>L. monocytogenes</i> showed a generation time of 0.4 days for 15% fat and 38% fat.	
		Storage of minced beef (pH 6.2, and 15 or 38% fat) at 46°F (8°C)	<i>L. monocytogenes</i> showed a generation time of 0.3 days for 15% fat and 0.35 days for 38% fat.	
	B – Growth of <i>L. monocytogenes</i> during refrigeration	Storage of minced beef (pH 6.2, and 15 or 38% fat) at 54°F (12°C)	<i>L. monocytogenes</i> showed a generation time of 0.2 days for 15% fat and 0.1 days for 38% fat.	
Frozen storage times and temperatures	B – Survival of <i>Trichinella spiralis</i>	Freezing ground pork for a given time-temperature interval	Trichina are non-infectious when frozen to the time-temperature relationship found with the equation: $\log(\text{time in hours}) = 5.98 + 0.40(\text{temperature } ^\circ\text{C})$ .	Kotula, A.W., A.K. Sharar, E. Paroczay, H.R. Gamble, K.D. Murrell, and L. Douglass. 1990. Infectivity of <i>Trichinella spiralis</i> from frozen pork. Journal of Food Protection. 53 (7) 571-573.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Frozen storage times and temperatures	B – Survival of <i>Trichinella spiralis</i>	Freezing ground pork for a given time-temperature interval	<p><i>Trichinella spiralis</i> will be destroyed at these specific time-temperature intervals</p> <p>0°F (-18°C) for 106 hours            -5°F (-21°C) for 82 hours            -10°F (-23°C) for 63 hours            -15°F (-26°C) for 48 hours            -20°F (-29°C) for 35 hours            -25°F (-32°C) for 22 hours            -30°F (-35°C) for 8 hours            -35°F (-37°C) for 1/2 hour</p>	<p>CFR 318.10 I (iv) Table 2.</p> <p>To access on the internet:</p> <p><a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301</a></p>



## **Fully-Cooked, Not Shelf Stable Process**

**Includes: Fully cooked hams, wieners, bologna, luncheon meats, summer sausage, etc.**



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	C – Excessive nitrite level in product	Addition of preblended cure including sodium nitrite	“[If] using sodium nitrite diluted [to 6.25% by weight] with sodium chloride, which is received from the manufacturer with a continuing letter of guarantee, then acute nitrite toxicity is not a problem.” (due to self-limiting, high, salt concentration)	Borchert, L.L., and R. G. Cassens. 1998. Chemical hazard analysis for sodium nitrite in meat curing. American Meat Institute Foundation Paper.
		Addition of pure sodium nitrite	“Extreme caution must be exercised if pure sodium nitrite is used.” “The conservative estimate for a lethal dose in humans is 14 mg/kg, meaning the dose would be 1 g [(0.0022 lb)] for a 70 kg [(154 lb)] adult and 0.2 g [(8.8x10 <sup>-5</sup> lb)] for a 15 kg [(33 lb)] child.”	<a href="http://www.ag.ohio-state.edu/~meatsci/borca2.htm">http://www.ag.ohio-state.edu/~meatsci/borca2.htm</a>
		Addition of sodium nitrite	Sodium nitrite can be added up to 200 parts per million (or an equivalent of potassium nitrite).	CFR 318.7I  To access on the internet:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301</a>
	B – Pathogen competition and growth against <i>Lactobacillus</i> and <i>Leuconostoc</i> growth	Adding 3-4% sodium lactate to cooked beef	If product contains 3-4% sodium lactate, the micro flora shift to primarily <i>Lactobacillus</i> during the 84 day shelf life at 32°F (0°C) indicating that a hazard is not likely to occur.	Papadopoulos, L.S., R.K. Miller, G.R. Acuff, C. Vanderzant, and H.R. Cross. 1991. Effect of sodium lactate on microbial and chemical composition of cooked beef during storage. Journal of Food Science. 56 (2) 341-347.
		Not adding 3-4% sodium lactate	<i>Leuconostoc</i> spp., organisms that are not a likely hazard, are the dominant bacteria after 56 days of storage at 32°F (0°C) when little or no sodium lactate is added to product.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – <i>L. monocytogenes</i> , <i>Staphylococcus aureus</i> , <i>S. typhimurium</i> , <i>E. coli</i> , and <i>Clostridium perfringens</i> growth	Addition of 2% sodium lactate (NaL) to cooked beef round stored for 28 days at 50°F (10°C)	There is no appreciable difference between the control (no lactate) and adding 2% NaL. <i>L. monocytogenes</i> , <i>S. typhimurium</i> , and <i>E. coli</i> , increased by at least 3 log units <i>S. aureus</i> grew 1.5 log units and <i>C. perfringens</i> was not detected after 7 days.	Miller, R.K. and G.R. Acuff, 1994, Sodium lactate affects pathogens in cooked beef. Journal of Food Science. 59 (1) 15-19.
		Addition of 3% sodium lactate to cooked beef round stored for 28 days at 50°F (10°C)	There was 2.5 log units of growth of <i>L. monocytogenes</i> with 3% lactate (no lactate, 4.5 log growth); 1 log decrease of <i>S. typhimurium</i> with 3% lactate (no lactate, 4 log growth); 1 log growth of <i>E. coli</i> (no lactate, 3 log growth); no change in count of <i>S. aureus</i> with no lactate or 3% lactate, and <i>C. perfringens</i> was not detected in any of the samples after 14 days.	
		Addition of 4% sodium lactate to cooked beef round stored for 28 days at 50°F (10°C)	There was less than 0.5 log change in <i>L. monocytogenes</i> , <i>S. aureus</i> , <i>S. typhimurium</i> , <i>E. coli</i> O157:H7, and no <i>C. perfringens</i> were detected after 14 days with 4% lactate. Those samples with no lactate <i>L. monocytogenes</i> , <i>S. typhimurium</i> , and <i>E. coli</i> O157:H7, increased by at least 3 log units <i>S. aureus</i> grew 1.5 log units and <i>C. perfringens</i> was not detected after 7 days.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of <i>L. monocytogenes</i>	Ground beef (55% moisture) with 2%NaCl, and 2-3% Sodium lactate stored at 68°F (20°C)	<i>L. monocytogenes</i> showed less than 0.5 log growth over 7 days.	Chen, N., and L.A. Shelef, 1992. Relationship between water activity, salts of lactic acid and growth of <i>Listeria monocytogenes</i> in a meat model system. Journal of Food Protection. 55 (8) 574-578.
		Ground beef (55% moisture) with 2-3% Sodium lactate stored at 68°F (20°C)	<i>L. monocytogenes</i> showed a 5 log growth in 5 days with 2% NaL.	
		Ground beef or chicken with added broth (2 – 3% NaCl, 140 ppm KNO <sub>2</sub> ) 4% Potassium or Sodium Lactate, stored at 95°F (35°C)	4% lactate inhibited growth by 1- 2 log units, however overall growth was 4-5 log units in 68 hours.	Shelef, L.A., and Q. Yang. 1991. Growth suppression of <i>Listeria monocytogenes</i> by lactates in broth, chicken and beef. Journal of Food Protection. 54 (4) 283-287.
		Ground beef or chicken with added broth (2 – 3% NaCl, 140 ppm KNO <sub>2</sub> ) 4% Potassium or Sodium Lactate, stored at 68°F (20°C)	4% lactate inhibited growth by 1-2 log units, however overall growth was 4-6 log units in 8 days.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of <i>L. monocytogenes</i>	Ground beef or chicken with added broth (2 – 3% NaCl, 140 ppm KNO <sub>2</sub> ) 4% Potassium or Sodium Lactate, stored at 68°F (20°C)	4% lactate inhibited growth by 2-4 log units in beef and no inhibition in chicken was found. Overall growth was 2-6 log units in 21 days.	Shelef and Yang 1991 cont'
		Bologna type sausage with 2% sodium lactate	No <i>L. monocytogenes</i> growth was detected when held at 41°F (5°C) for 28 days.	Qvist, S., K. Sehested, and P. Zeuthen. 1994. Growth suppression of <i>Listeria monocytogenes</i> in a meat product. International Journal of Food Microbiology. 24 (1/2) 283-293.
		Bologna type sausage with 2% sodium lactate and 0.25% glucono-delta-lactone	No <i>L. monocytogenes</i> growth was detected when held at 50°F (10°C) or less for 35 days.	
		Bologna type sausage with 2% sodium lactate and 0.50% glucono-delta-lactone		



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of <i>L. monocytogenes</i>	Cervelat (pork and beef sausage) with 2.5% NaCl, 2.5% sodium lactate and 0.25% sodium acetate, vacuum packaged and stored at 40°F (4°C)	With the addition of sodium lactate and sodium acetate there was no <i>L. monocytogenes</i> log change detected in 35 days at 40°F (4°C).	Blom, H., E. Nerbrink, R. Dainty, T. Hagtvedt, E. Borch, H. Nissen, and T. Nesbakken. 1997. Addition of 2.5% lactate and 0.25% acetate controls growth of <i>Listeria monocytogenes</i> in vacuum-packed, sensory acceptable cervelat sausage and cooked ham stored at 4°C. International Journal of Food Microbiology. 38(1) 71-76.
		Cervelat (pork and beef sausage) with 2.5% NaCl, 2.5% sodium lactate and 0.25% sodium acetate, vacuum packaged and stored at 48°F (9°C)	With the addition of sodium lactate and sodium acetate there was no <i>L. monocytogenes</i> log change detected in 35 days at 48°F (9°C).	
		Cooked ham sliced and vacuum packaged, stored at 40°F (4°C)	There was no log growth of <i>L. monocytogenes</i> in 35 days at 40°F (4°C).	
		Cooked ham sliced and vacuum packaged, stored at 48°F (9°C)	There was a 2.5 log growth of <i>L. monocytogenes</i> in 35 days at 48°F (9°C).	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – <i>L. monocytogenes</i> survival and growth	Use of various liquid smoke products at 0.25% and 0.5%	<p>0.25% Char-Sol and Arro-Smoke P50 resulted in a 5 log reduction of <i>L. monocytogenes</i> in 4 hours.</p> <p>0.25% Chardex Hickory resulted in a 5 log reduction of <i>L. monocytogenes</i> in 24 hours.</p> <p>0.25% CharSol PN-9 resulted in a 5 log reduction of <i>L. monocytogenes</i> in 48 hours.</p> <p>0.25% Charoil Hickory resulted in a 5 log reduction of <i>L. monocytogenes</i> in 96 hours.</p> <p>0.5% Chardex Hickory, Arro-Smoke P50, and CharSol-10, resulted in a 5 log reduction of <i>L. monocytogenes</i> in 4 hours.</p> <p>0.5% CharSol PN-9 and Charoil Hickory resulted in a 5 log reduction of <i>L. monocytogenes</i> in 24 hours.</p>	Messina, M.C., H.A. Ahmad, J.A. Marchello, C.P. Gerba, and M.W. Paquette. 1988. The effect of liquid smoke on <i>Listeria monocytogenes</i> . Journal of Food Protection. 51 (8) 629-631.
	B – Growth of <i>L. monocytogenes</i>	<p>pH of product is near or below 5.0, stored at 40°F (4.4°C)</p> <p>Roast Beef (&lt;1% NaCl, 4.61-5.31pH after week 2)</p>	<p><i>Listeria monocytogenes</i> is not likely to grow; however if contaminated prior to storage it will not be destroyed.</p> <p>Roast beef – <i>L. monocytogenes</i> changed in log units decline 1 unit to increase 2 units in 6 weeks.</p>	Glass, K.A., and M.P. Doyle. 1989. Fate of <i>Listeria monocytogenes</i> in processed meat products during refrigerated storage. Applied and Environmental Microbiology. 55 (6) 1565-1569.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of <i>L. monocytogenes</i>	PH of product is near or above 6.0 Cooked ham (2.5-3% NaCl, 6.52-5.13 pH) Bologna (2.3-2.6% NaCl, 6.46-5.06 pH) Wieners (2.4-2.6% NaCl, 6.18-5.44 pH)	A hazard is likely if contaminated with <i>Listeria monocytogenes</i> . It will continue to grow and create a risk.  Cooked ham – 3 to 4 log increase Bologna – 3 to 4 log increase Wieners – 0.5 to 3 log increase	Glass and Doyle 1989 cont'          Kant-Muermans, M.L.T., and F.K. Stekelenburg, 1998. The influence of different additives on the quality of cooked ham products. TNO Nutrition and Food Research Institute. Project number 847655.
		Cooked cured ham (2.2% NaCl) vacuum packaged and stored at 40°F (4°C) for 20 days	Storage at 40°F (4°C) resulted in a 1 log growth of <i>L. monocytogenes</i> in 20 days.	
		Cooked cured ham (2.2% NaCl) with 1.5% Sodium Lactate, vacuum packaged and stored at 40°F (4°C) for 40 days	Treatment with 1.5% sodium lactate resulted in no log growth of <i>L. monocytogenes</i> over 40 days.	
		Cooked cured ham (2.2% NaCl) with 2% Sodium Lactate, vacuum packaged and stored at 40°F (4°C) for 40 days	Treatment with 2% sodium lactate resulted in no log growth of <i>L. monocytogenes</i> over 40 days.	



## Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of <i>L. monocytogenes</i>	Cooked cured ham (2.2% NaCl) with 0.1% di-acetate, vacuum packaged and stored at 40°F (4°C) for 15 days	Treatment with 0.1% di-acetate resulted in 1 log growth of <i>L. monocytogenes</i> over 15 days.	Kant-Muermans, and Stekelenburg 1998 cont'
		Cooked cured ham (2.2% NaCl) with 0.2% di-acetate, vacuum packaged and stored at 40°F (4°C) for 40 days	Treatment with 0.2% di-acetate resulted in no log growth of <i>L. monocytogenes</i> over 40 days.	
		Cooked cured ham (2.2% NaCl) with 0.9% Sodium Lactate and 0.1% di-acetate, vacuum packaged and stored at 40°F (4°C) for 40 days	Treatment with 0.9% sodium lactate and 0.1% di-acetate resulted in no log growth of <i>L. monocytogenes</i> over 40 days.	
		Cooked cured ham (2.2% NaCl) with 1.5% Sodium Lactate and 0.1% di-acetate, vacuum packaged and stored at 40°F (4°C) for 40 days	Treatment with 1.5% sodium lactate and 0.1% di-acetate resulted in no log growth of <i>L. monocytogenes</i> over 40 days.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of <i>L. monocytogenes</i>	Cooked cured ham (2.2% NaCl) with 1% sodium citrate (Ional), vacuum packaged and stored at 40°F (4°C) for 15 days	Treatment with 1% sodium citrate (Ional) resulted in greater than 5 log growth of <i>L. monocytogenes</i> over 15 days.	Kant-Muermans, and Stekelenburg 1998 cont'
	B – Growth of <i>C. perfringens</i>	Vacuum-packaged, cook-in-bag turkey pH 6, 0.3% sodium pyrophosphate and 3% NaCl and held at 40°F (4°C), 59°F (15°C), or 82°F (28°C)	There was no <i>C. perfringens</i> growth at 40°F (4°C) or 59°F (15°C) for 28 days. At 28°F (82°C) there was no growth in 12 hours.	Juneja, V.K., and B.S. Marmer. 1996. Growth of <i>Clostridium perfringens</i> from spore inocula in <i>sous-vide</i> turkey products. Journal of International Food Microbiology. 32 (1-2) 115-123.
		Vacuum-packaged, cook-in-bag turkey pH 6, 0.3% sodium pyrophosphate and 2% or less NaCl and held at 40°F (4°C), 59°F (15°C), or 82°F (28°C)	There was no <i>C. perfringens</i> growth at 40°F (4°C) for 28 days and at 59°F (15°C) and 82°F (28°C) there was no growth for 8 hours.	
Thawing	B – pathogen growth	Thawing ready-to-cook poultry	Thawing media (water, air, etc.) shall not exceed 70°F.	MPI Regulations, Section 381.65(h)(1)  Access on the internet at:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html</a>



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Fermentation	B- Staphylococcal enterotoxin production	Using a starter culture to reduce meat pH	Meat pH should decline to 5.0 within 12 hours, to prevent Staphylococcal enterotoxin production.	Good Manufacturing Practices for Fermented Dry and Semi-Dry Sausage Products, American Meat Institute Foundation, 1997.
	B – Potential Staphylococcus growth	Fermentation to pH 5.3 or less	<p>(Fermentation Temperature (°F)–60) X hours = degree hours</p> <p>Process acceptable if:</p> <p>Fewer than 1200 degree hours when the lowest fermentation temperature is less than 90°F (32°C).</p> <p>Fewer than 1000 degree hours when the highest fermentation temperature is between 90°F (32°C) and 100°F (38°C).</p> <p>Fewer than 900 degree hours when the highest fermentation temperature is greater than 100°F (38°C).</p>	
	B – Survival of <i>L. monocytogenes</i>	Cooking fermented sausage at temperatures ranging from 120°F (48.9°C) to 140°F (60°C)	<i>Listeria monocytogenes</i> has a D-value of 98.6 minutes at 120°F (48.9°C), and 9.13 minutes at 140°F (60°C).	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Fermentation	B - Survival of <i>Salmonella seftenberg</i> , <i>C. perfringens</i> , and <i>E. coli</i> O128:B12	Dried fermented turkey sausage step-wise heat treated at 81°F (27°C) for 3 hours, 90°F (32°C) for 4 hours, 115°F (46°C) for 5 hours, spray cooled to 61 to 64°F (16 to 18°C) and dried at 50°F (10°C) 72% RH for 8 days	<i>S. seftenberg</i> decreased 1.5 to 20 log units.  <i>C. perfringens</i> decreased 2 to 3.6 log units.  <i>E. coli</i> O128:B12 decreased 1.4 to 2.1 log units.	Baran, W.L., and K.E. Stevenson. 1975. Survival of selected pathogens during processing of a fermented turkey sausage. <i>Journal of Food Science</i> . 40 (3) 618-620.
Cook-in-bag packaging	B – <i>Clostridium perfringens</i> and <i>Salmonella</i> survival in roast beef	Beef roasts cooked in plastic bags, in a water bath to 140°F (60°C) internal temperature for 12 minutes	<i>Salmonella</i> was eliminated and <i>C. perfringens</i> was reduced 3 log units.	Smith, A.M., D.A. Evans, and B.M. Buck. 1981. Growth and survival of <i>Clostridium perfringens</i> in rare roast beef prepared in a water bath. <i>Journal of Food Protection</i> . 44: 9-14.
	B – <i>Clostridium perfringens</i> growth during storage of cooked ground beef	After cooking ground beef product (3% salt, and pH 5.5) to 160°F (71.1°C), cooled to 32°F (0°C) then stored at 82°F (28°C), in vacuumized, cook-in-bag	No hazard is likely to occur from <i>Clostridium perfringens</i> within 24 hours at 82°F (28°C), as no growth occurred. 36 hours were required for 1 log growth.	Juneja, V.K., and W.M. Majka, 1995, Outgrowth of <i>Clostridium perfringens</i> spores in cook-in-bag beef products. <i>Journal of Food Safety</i> . 15 (1) 21-34.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cook-in-bag packaging	B – <i>Clostridium perfringens</i> growth during storage of cooked ground beef	After cooking ground beef product (0% salt, pH 7.0) to 160°F (71.1°C), cooled to 32°F (0°C) then stored at 59°F (15°C), in vacuumized, cook-in-bag	Growth of <i>Clostridium perfringens</i> was delayed (less than 1 log increase) 5 days, and posed no hazard in that time.	Juneja and Majka 1995 cont'
		After cooking ground beef product (3% salt, and pH 7.0) to 160°F (71.1°C), cooled to 32°F (0°C) then stored at 59°F (15°C), in vacuumized, cook-in-bag	Growth of <i>Clostridium perfringens</i> was delayed (less than 1 log increase) 7 days, and posed no hazard in that time.	
		After cooking ground beef product (3% salt, and pH 5.5) to 160°F (71.1°C), cooled to 32°F (0°C) then stored at 59°F (15°C), in vacuumized, cook-in-bag	Growth of <i>Clostridium perfringens</i> was delayed (less than 1 log increase) 21 days, and posed no hazard in that time.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cook-in-bag packaging	B – <i>Clostridium perfringens</i> growth during storage of cooked ground beef	After cooking ground beef to an internal temperature of 160°F (71.1°C), cooled to 32°F (0°C) then stored at 40°F (4°C) in vacuum packaged, cook-in bag, regardless of salt content or pH.	Less than 1 log of growth of <i>Clostridium perfringens</i> was detected, even after 28 days, no hazard is posed.	Juneja and Majka 1995 cont'
Cooking	B – <i>L. monocytogenes</i> , survival	Cooking ham to minimum internal temperature of 150°F (65°C) and maintaining that internal temperature for at least 40 minutes	<i>Listeria monocytogenes</i> is destroyed (no detection after 50 days) provided that product is cooked to an internal temperature of 150°F (65°C) and maintained at that temperature for 40 minutes.	Carlier, V., J.C. Augustin, and J. Rozier. 1996. Destruction of <i>Listeria monocytogenes</i> during a ham cooking process. Journal of Food Protection. 59 (6) 592-595.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – <i>L. monocytogenes</i> , survival	Cooking Ground Beef to 125°F (52°C), 135°F (57°C) and 145°F (63°C) (internal)	<p><i>Listeria monocytogenes</i> showed a 4 log reduction in ground beef at these temperatures, in these time-internal temperature limits.</p> <p>125°F (52°C) internal for 325 min.</p> <p>135°F (57°C) internal for 25 min.</p> <p>145°F (63°C) internal for 2 min.</p>	Fain, A.R., J.E. Line, A. B. Moran, L.M. Martin, R.V. Lechowich, J.M. Carosella, and W.L. Brown. 1991. Lethality of heat to <i>Listeria monocytogenes</i> Scott A: D-value and z-value determinations in ground beef and turkey. Journal of Food Protection. 54 (10) 756-761.
		Cooking Ground Turkey to 160°F (71.1°C) internal	After cooking for 2 minutes at 160°F (71.1°C) internal, <i>L. monocytogenes</i> was reduced by a 5 to 6 log reduction.	
		Cooking ground beef roast at temperatures ranging from 130°F (54.4°C) to 154°F (62.8°C)	<i>Listeria monocytogenes</i> has a D-value of 22.4 minutes at 130°F (54.4°C), and 2.56 minutes at 154°F (62.8°C).	Schoeni, J.L., K. Brunner, and M.P. Doyle. 1991. Rates of thermal inactivation of <i>Listeria monocytogenes</i> in beef and fermented beaker sausage. Journal of Food Protection. 54 (5) 334-337.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – <i>L. monocytogenes</i> , survival	Cooking pork and turkey tumbled and pork emulsion type sausages to 158°F (70°C)	When product is cooked to an internal temperature of at least 158°F (70°C) <i>L. monocytogenes</i> is destroyed.	Samelis, J., and J. Metaxopoulos, 1999. Incidence and principal sources of <i>Listeria</i> spp. and <i>Listeria monocytogenes</i> contamination in processed meats and a meat processing plant. Food Microbiology. 16 (5) 465-477.
		Cooking chicken breast to specific internal temperatures	The following log reductions were reached when cooking chicken breast to these specific instantaneous internal temperatures.  150°F (65.6°C): 2.8 log reduction 160°F (71.1°C): 1.8 log reduction 165°F (73.9°C): 4.4 log reduction 170°F (76.7°C): 5.3 log reduction 180°F (82.2°C): 4.85 log reduction	Carpenter, S.L., and M.A. Harrison. 1989. Survival of <i>Listeria monocytogenes</i> on processed poultry. Journal of Food Science. 54 (3) 556-557.
	B – <i>L. monocytogenes</i> heat resistance	Addition of partially cooked ham rework	When cooking ham to 140°F (60°C), rework, previously heated at 108°F (42°C) for 1 hr (heat shocked), resulted in <i>L. monocytogenes</i> with more heat resistance than <i>L. monocytogenes</i> in rework, which was previously heated at 108°F (42°C) for 20 minutes.	Carlier V., J.C. Augustin, and J. Rozier. 1996. Heat resistance of <i>Listeria monocytogenes</i> : D- and z-values in ham. Journal of Food Protection. 59 (6) 588-591.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – <i>L. monocytogenes</i> heat resistance	Holding product between 104°F (40°C) and 118°F (48°C) for 3 to 20 minutes	D-value for <i>L. monocytogenes</i> increases up to 2.3 fold when cooked at 131°F (55°C). The time allotted to destroy <i>L. monocytogenes</i> must increase correspondingly.	Linton, R.H., M.D. Pierson, and J.R. Bishop. 1990. Increase in heat resistance of <i>Listeria monocytogenes</i> Scott A by sublethal heat shock. Journal of Food Protection. 53 (11) 924-927.
	B – <i>Clostridium perfringens</i> survival during cooking process	Cooking Ground Beef to 140°F (60°C)	Cooking beef to an internal temperature of 140°F (60°C) destroys <i>Clostridium perfringens</i> and the risk of spore germination is eliminated if the temperature is constantly raised by at least 13°C/hour. Research showed same results with fluid thioglycollate medium (FTM).	Shigehisa, T., T. Nakagami, and S. Taji. 1985. Influence of heating and cooling rates on spore germination and growth of <i>Clostridium perfringens</i> in media and roast beef. Japanese Journal of Veterinary Science. 47 (2) 259-267.
		Cooking ground beef to 135°F (57°C) internal temperature	<i>C. perfringens</i> showed a 5 log reduction of vegetative cells within 50 minutes at 135°F (57°C) in ground beef.	Roy, R.J., F.F. Busta, and D.R. Thompson. 1981. Thermal inactivation of <i>Clostridium perfringens</i> after growth at several constant and linearly rising temperatures. Journal of Food Science. 46: 1586-1591.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – Survival of <i>C. perfringens</i> vegetative cells	Reheating vacuumized, cooked beef to internal temperature of 149°F (65°C)	Reheating product to an internal temperature of 149°F (65°C) before consumption will kill vegetative cells preventing a hazard.	Juneja, V.K., B.S. Marmer, and A.J. Miller. 1994. Growth and sporulation potential of <i>Clostridium perfringens</i> in aerobic and vacuum-packaged cooked beef. Journal of Food Protection. 57 (5) 393-398.
		Heating previously cooked ground beef containing 0.15% to 0.3% sodium pyrophosphate to 149°F (65°C)	When ground beef containing 0.15% to 0.3% sodium pyrophosphate is heated to 149°F (65°C) for 30 seconds 8 log units of <i>C. perfringens</i> are destroyed.	Juneja, V.K., B.S. Marmer. 1998. Thermal inactivation of <i>Clostridium perfringens</i> vegetative cells in ground beef and turkey as affected by sodium pyrophosphate. Food Microbiology. 15 (3) 281-287.
		Heating previously cooked turkey containing 0.15% to 0.3% sodium pyrophosphate to 140°F (60°C)	When turkey containing 0.15% to 0.3% sodium pyrophosphate is heated to 140°F (60°C) for 30 seconds 8 log units of <i>C. perfringens</i> are destroyed.	
	B – Stability of <i>C. perfringens</i> enterotoxin through cooking	Cooking chicken gravy to 142°F (61°C) for 23.8 minutes	<i>C. perfringens</i> enterotoxin is destroyed after cooking chicken gravy at 142°F (61°C) for at least 23.8 minutes.	Bradshaw, J.G. G.N. Stelma, and V.I. Jones, et al. 1982. Thermal inactivation of <i>Clostridium perfringens</i> enterotoxin in buffer and chicken gravy. Journal of Food Science. 47: 914-916.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – <i>E. coli</i> O157:H7 survival during cooking process	Cooking ground beef to specific internal temperatures: 130°F (54.4°C) 135°F (57.2°C) 138°F (58.9°C) 140°F (60°C) 145°F (62.8°C) 148°F (64.3°C)	D-values for <i>E. coli</i> O157:H7 in ground beef for these specific internal temperatures are: 130°F (54.4°C): 2,390 min. 135°F (57.2°C): 270 min. 138°F (58.9°C): 70 min. 140°F (60°C): 45 min. 145°F (62.8°C): 24 min. 148°F (64.3°C): 9.6 min.	Doyle, M.P., J.L. Schoeni. 1984. Survival and growth characteristics of <i>Escherichia coli</i> associated with hemorrhagic colitis. Applied and Environmental Microbiology. 10: 855-856.
		Cooking Ground Beef to 155°F (68°C)	By heating the ground beef to 155°F (68°C) a hazard posed by <i>E. coli</i> O157:H7 is not likely to occur.	Mermelstein, N.H. 1993. Controlling <i>E. coli</i> O157:H7 in meat. Food Technology. 47 (4) 90-91.
		Cooking ground beef to 135°F (57°C) internal temperature	<i>E. coli</i> showed a 7 log reduction in 30 minutes at 135°F (57°C) in ground beef.	Line, J.E., A.R. Fain Jr., A.B. Moran, L.M. Martin, R.V. Lechowich, J.M. Carosella, and W.L. Brown. 1991. Lethality of Heat to <i>Escherichia coli</i> O157:H7: D-value and Z-value determinations in ground beef. Journal of Food Protection. 54 (10) 762-766.
		Cooking ground beef to 145°F (63°C) internal temperature	<i>E. coli</i> showed a 7 log reduction in 1 minute at 145°F (63°C) internal in ground beef.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – <i>E. coli</i> O157:H7 survival during cooking process	Cooking Ground Turkey, Pork and Lamb:	<p><i>E. coli</i> O157:H7 is reduced by 1 log unit in ground turkey, pork and lamb at these time and temperature levels.</p> <p>131°F (55°C) internal for 11.9 min.</p> <p>135.5°F (57.5°C) internal for 3.7 min.</p> <p>140°F (60°C) internal for 2.0 min.</p> <p>144.5°F (62.5°C) internal for 0.9 min.</p> <p>149°F (65°C) internal for 0.4 min.</p>	Juneja, V.K., and B.S. Marmer. 1999. Lethality of heat to <i>Escherichia coli</i> O157:H7: D- and z- value determinations in turkey, lamb, and pork. Food Research International. 32 (1) 23-28.
	B – <i>E. coli</i> O128, <i>Salmonella</i> , <i>Staphylococcus aureus</i> survival during cooking process	Dry-roasting beef to 140°F (60°C) in oven temperatures at 230°F (110°C) to 266°F (130°C)	When dry-oven-roasting roast beef the internal temperature must reach 140°F (60°C) to ensure the destruction of <i>E. coli</i> O128, <i>Staphylococcus aureus</i> , and <i>Salmonella</i> . Oven temperature did not effect results as long as internal temperature reached 140°F (60°C).	Shigehisa, T., T. Nakagami, S. Taji, and G. Sakaguchi. 1985. Destruction of salmonellae, <i>Escherichia coli</i> , and <i>Staphylococcus aureus</i> inoculated into and onto beef during dry-oven roasting. Japanese Journal of Veterinary Sciences. 47 (2) 251-257.
	B – <i>Salmonella</i> survival during cooking process	Dry roasting of large beef roasts at oven temperatures of 250°F (121°C) or 275°F (135°C)	<p><i>Salmonella</i> will be destroyed (7 log reduction) if roasts (16-18 pounds) are dry roasted to these specifications:</p> <p>250°F (121°C) oven, internal temperature of at least 130°F (54.4°C).</p> <p>275°F (135°C) oven, internal temperature of at least 125°F (51.6°C).</p>	Goodfellow, S.J., and W.L. Brown. 1978. Fate of <i>Salmonella</i> inoculated into beef for cooking. Journal of Food Protection. 41 (8) 598-605.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – <i>Salmonella</i> survival during cooking process	Dry Roasting small (less than 10 pounds) beef roasts in oven temperatures of 275°F (135°C) or less	<i>Salmonella</i> are not fully destroyed when dry roasting beef roasts of less than 10 pounds in an oven at 275°F (135°C), or less, when heated to an internal temperature of 135°F (57.2°C), however there was a 5 log reduction.	Goodfellow and Brown 1978 cont'
		Including steam cooking for at least 30 minutes in total cooking time	<i>Salmonella</i> will be destroyed if large beef roasts (16-18 pounds) are cooked to an internal temperature of at least 130°F (54.4°C) using at least 30 minutes of steam in the cooking process where the oven temperature is 175°F (79.4°C).	
		Water cooking in 165°F (73.8°C) water	<p><i>Salmonella</i> will be destroyed (7 log reduction) at these time-internal temperature levels in 165°F (73.8°C) water.</p> <p>125°F (51.6°C) internal for more than 7 hours.</p> <p>130°F (54.4°C) internal for 60 minutes.</p> <p>135°F (57.2°C) internal for 3 minutes.</p> <p>Above 135°F (57.2°C) internal instantaneous.</p>	
	B – <i>Salmonella</i> and <i>L. monocytogenes</i> survival during cooking process	Cooking times and internal temperatures of meat products to achieve lethality	AMI Process Lethality Equation calculates f-values for individual processes based upon cooking and cooling times and temperatures.	Access AMI Process Lethality Equation at: <a href="http://www.amif.org/factsand.htm">http://www.amif.org/factsand.htm</a>



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – <i>Salmonella</i> and <i>L. monocytogenes</i> survival during cooking process	Cooking cooked beef, roast beef, and cooked corned beef products	Time and temperature combinations to meet either a 6.5 or a 7.0 log reduction in <i>Salmonella</i> .	<p>MPI Regulations, Section 318.17(a)</p> <p>Appendix A to FSIS Compliance Guidelines</p> <p>Access Appendix A, on internet at:  <a href="http://www.fsis.usda.gov/oa/fr/95033f%2Da.htm">www.fsis.usda.gov/oa/fr/95033f%2Da.htm</a></p>
		Fully cooking ground beef patties	Fully cooked patties should reach an instantaneous internal temperature of 160°F (71°C).	<p>MPI Regulations, Section 318.23(b)(1)(i)</p> <p>Access on internet at:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301</a></p>
		Cooking cured and non-cured poultry products	<p>Cooked, uncured poultry products should reach an instantaneous internal temperature of 160°F (71°C).</p> <p>Cured and smoked poultry products should reach instantaneous internal 155°F (68°C).</p>	<p>MPI Regulations, Section 318.150(b)</p> <p>Access on internet at:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301</a></p>



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – <i>L. monocytogenes</i> , survival	Cooking Ground Beef to 125°F (52°C), 135°F (57°C) and 145°F (63°C) (internal)	<p><i>Listeria monocytogenes</i> showed a 4 log reduction in ground beef at these temperatures, in these time-internal temperature limits.</p> <p>125°F (52°C) internal for 325 min.</p> <p>135°F (57°C) internal for 25 min.</p> <p>145°F (63°C) internal for 2 min.</p>	Fain, A.R., J.E. Line, A. B. Moran, L.M. Martin, R.V. Lechowich, J.M. Carosella, and W.L. Brown. 1991. Lethality of heat to <i>Listeria monocytogenes</i> Scott A: D-value and z-value determinations in ground beef and turkey. Journal of Food Protection. 54 (10) 756-761.
		Cooking Ground Turkey to 160°F (71.1°C) internal	After cooking for 2 minutes at 160°F (71.1°C) internal, <i>L. monocytogenes</i> was reduced by a 5 to 6 log reduction.	
		Cooking ground beef roast at temperatures ranging from 130°F (54.4°C) to 154°F (62.8°C)	<i>Listeria monocytogenes</i> has a D-value of 22.4 minutes at 130°F (54.4°C), and 2.56 minutes at 154°F (62.8°C).	Schoeni, J.L., K. Brunner, and M.P. Doyle. 1991. Rates of thermal inactivation of <i>Listeria monocytogenes</i> in beef and fermented beaker sausage. Journal of Food Protection. 54 (5) 334-337.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – <i>L. monocytogenes</i> , survival	Cooking pork and turkey tumbled and pork emulsion type sausages to 158°F (70°C)	When product is cooked to an internal temperature of at least 158°F (70°C) <i>L. monocytogenes</i> is destroyed.	Samelis, J., and J. Metaxopoulos, 1999. Incidence and principal sources of <i>Listeria</i> spp. and <i>Listeria monocytogenes</i> contamination in processed meats and a meat processing plant. Food Microbiology. 16 (5) 465-477.
		Cooking chicken breast to specific internal temperatures	The following log reductions were reached when cooking chicken breast to these specific instantaneous internal temperatures.  150°F (65.6°C): 2.8 log reduction 160°F (71.1°C): 1.8 log reduction 165°F (73.9°C): 4.4 log reduction 170°F (76.7°C): 5.3 log reduction 180°F (82.2°C): 4.85 log reduction	Carpenter, S.L., and M.A. Harrison. 1989. Survival of <i>Listeria monocytogenes</i> on processed poultry. Journal of Food Science. 54 (3) 556-557.
	B – <i>L. monocytogenes</i> heat resistance	Addition of partially cooked ham rework	When cooking ham to 140°F (60°C), rework, previously heated at 108°F (42°C) for 1 hr (heat shocked), resulted in <i>L. monocytogenes</i> with more heat resistance than <i>L. monocytogenes</i> in rework, which was previously heated at 108°F (42°C) for 20 minutes.	Carlier V., J.C. Augustin, and J. Rozier. 1996. Heat resistance of <i>Listeria monocytogenes</i> : D- and z-values in ham. Journal of Food Protection. 59 (6) 588-591.



Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – <i>L. monocytogenes</i> heat resistance	Holding product between 104°F (40°C) and 118°F (48°C) for 3 to 20 minutes	D-value for <i>L. monocytogenes</i> increases up to 2.3 fold when cooked at 131°F (55°C). The time allotted to destroy <i>L. monocytogenes</i> must increase correspondingly.	Linton, R.H., M.D. Pierson, and J.R. Bishop. 1990. Increase in heat resistance of <i>Listeria monocytogenes</i> Scott A by sublethal heat shock. Journal of Food Protection. 53 (11) 924-927.
	B – <i>Clostridium perfringens</i> survival during cooking process	Cooking Ground Beef to 140°F (60°C)	Cooking beef to an internal temperature of 140°F (60°C) destroys <i>Clostridium perfringens</i> and the risk of spore germination is eliminated if the temperature is constantly raised by at least 13°C/hour. Research showed same results with fluid thioglycollate medium (FTM).	Shigehisa, T., T. Nakagami, and S. Taji. 1985. Influence of heating and cooling rates on spore germination and growth of <i>Clostridium perfringens</i> in media and roast beef. Japanese Journal of Veterinary Science. 47 (2) 259-267.
		Cooking ground beef to 135°F (57°C) internal temperature	<i>C. perfringens</i> showed a 5 log reduction of vegetative cells within 50 minutes at 135°F (57°C) in ground beef.	Roy, R.J., F.F. Busta, and D.R. Thompson. 1981. Thermal inactivation of <i>Clostridium perfringens</i> after growth at several constant and linearly rising temperatures. Journal of Food Science. 46: 1586-1591.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – Survival of <i>C. perfringens</i> vegetative cells	Reheating vacuumized, cooked beef to internal temperature of 149°F (65°C)	Reheating product to an internal temperature of 149°F (65°C) before consumption will kill vegetative cells preventing a hazard.	Juneja, V.K., B.S. Marmer, and A.J. Miller. 1994. Growth and sporulation potential of <i>Clostridium perfringens</i> in aerobic and vacuum-packaged cooked beef. Journal of Food Protection. 57 (5) 393-398.
		Heating previously cooked ground beef containing 0.15% to 0.3% sodium pyrophosphate to 149°F (65°C)	When ground beef containing 0.15% to 0.3% sodium pyrophosphate is heated to 149°F (65°C) for 30 seconds 8 log units of <i>C. perfringens</i> are destroyed.	Juneja, V.K., B.S. Marmer. 1998. Thermal inactivation of <i>Clostridium perfringens</i> vegetative cells in ground beef and turkey as affected by sodium pyrophosphate. Food Microbiology. 15 (3) 281-287.
		Heating previously cooked turkey containing 0.15% to 0.3% sodium pyrophosphate to 140°F (60°C)	When turkey containing 0.15% to 0.3% sodium pyrophosphate is heated to 140°F (60°C) for 30 seconds 8 log units of <i>C. perfringens</i> are destroyed.	
	B – Stability of <i>C. perfringens</i> enterotoxin through cooking	Cooking chicken gravy to 142°F (61°C) for 23.8 minutes	<i>C. perfringens</i> enterotoxin is destroyed after cooking chicken gravy at 142°F (61°C) for at least 23.8 minutes.	Bradshaw, J.G. G.N. Stelma, and V.I. Jones, et al. 1982. Thermal inactivation of <i>Clostridium perfringens</i> enterotoxin in buffer and chicken gravy. Journal of Food Science. 47: 914-916.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – <i>E. coli</i> O157:H7 survival during cooking process	Cooking ground beef to specific internal temperatures: 130°F (54.4°C) 135°F (57.2°C) 138°F (58.9°C) 140°F (60°C) 145°F (62.8°C) 148°F (64.3°C)	D-values for <i>E. coli</i> O157:H7 in ground beef for these specific internal temperatures are: 130°F (54.4°C): 2,390 min. 135°F (57.2°C): 270 min. 138°F (58.9°C): 70 min. 140°F (60°C): 45 min. 145°F (62.8°C): 24 min. 148°F (64.3°C): 9.6 min.	Doyle, M.P., J.L. Schoeni. 1984. Survival and growth characteristics of <i>Escherichia coli</i> associated with hemorrhagic colitis. Applied and Environmental Microbiology. 10: 855-856.
		Cooking Ground Beef to 155°F (68°C)	By heating the ground beef to 155°F (68°C) a hazard posed by <i>E. coli</i> O157:H7 is not likely to occur.	Mermelstein, N.H. 1993. Controlling <i>E. coli</i> O157:H7 in meat. Food Technology. 47 (4) 90-91.
		Cooking ground beef to 135°F (57°C) internal temperature	<i>E. coli</i> showed a 7 log reduction in 30 minutes at 135°F (57°C) in ground beef.	Line, J.E., A.R. Fain Jr., A.B. Moran, L.M. Martin, R.V. Lechowich, J.M. Carosella, and W.L. Brown. 1991. Lethality of Heat to <i>Escherichia coli</i> O157:H7: D-value and Z-value determinations in ground beef. Journal of Food Protection. 54 (10) 762-766.
		Cooking ground beef to 145°F (63°C) internal temperature	<i>E. coli</i> showed a 7 log reduction in 1 minute at 145°F (63°C) internal in ground beef.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – <i>E. coli</i> O157:H7 survival during cooking process	Cooking Ground Turkey, Pork and Lamb:	<p><i>E. coli</i> O157:H7 is reduced by 1 log unit in ground turkey, pork and lamb at these time and temperature levels.</p> <p>131°F (55°C) internal for 11.9 min.</p> <p>135.5°F (57.5°C) internal for 3.7 min.</p> <p>140°F (60°C) internal for 2.0 min.</p> <p>144.5°F (62.5°C) internal for 0.9 min.</p> <p>149°F (65°C) internal for 0.4 min.</p>	Juneja, V.K., and B.S. Marmer. 1999. Lethality of heat to <i>Escherichia coli</i> O157:H7: D- and z- value determinations in turkey, lamb, and pork. Food Research International. 32 (1) 23-28.
	B – <i>E. coli</i> O128, <i>Salmonella</i> , <i>Staphylococcus aureus</i> survival during cooking process	Dry-roasting beef to 140°F (60°C) in oven temperatures at 230°F (110°C) to 266°F (130°C)	When dry-oven-roasting roast beef the internal temperature must reach 140°F (60°C) to ensure the destruction of <i>E. coli</i> O128, <i>Staphylococcus aureus</i> , and <i>Salmonella</i> . Oven temperature did not effect results as long as internal temperature reached 140°F (60°C).	Shigehisa, T., T. Nakagami, S. Taji, and G. Sakaguchi. 1985. Destruction of salmonellae, <i>Escherichia coli</i> , and <i>Staphylococcus aureus</i> inoculated into and onto beef during dry-oven roasting. Japanese Journal of Veterinary Sciences. 47 (2) 251-257.
	B – <i>Salmonella</i> survival during cooking process	Dry roasting of large beef roasts at oven temperatures of 250°F (121°C) or 275°F (135°C)	<p><i>Salmonella</i> will be destroyed (7 log reduction) if roasts (16-18 pounds) are dry roasted to these specifications:</p> <p>250°F (121°C) oven, internal temperature of at least 130°F (54.4°C).</p> <p>275°F (135°C) oven, internal temperature of at least 125°F (51.6°C).</p>	Goodfellow, S.J., and W.L. Brown. 1978. Fate of <i>Salmonella</i> inoculated into beef for cooking. Journal of Food Protection. 41 (8) 598-605.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – <i>Salmonella</i> survival during cooking process	Dry Roasting small (less than 10 pounds) beef roasts in oven temperatures of 275°F (135°C) or less	<i>Salmonella</i> are not fully destroyed when dry roasting beef roasts of less than 10 pounds in an oven at 275°F (135°C), or less, when heated to an internal temperature of 135°F (57.2°C), however there was a 5 log reduction.	Goodfellow and Brown 1978 cont'
		Including steam cooking for at least 30 minutes in total cooking time	<i>Salmonella</i> will be destroyed if large beef roasts (16-18 pounds) are cooked to an internal temperature of at least 130°F (54.4°C) using at least 30 minutes of steam in the cooking process where the oven temperature is 175°F (79.4°C).	
		Water cooking in 165°F (73.8°C) water	<i>Salmonella</i> will be destroyed (7 log reduction) at these time-internal temperature levels in 165°F (73.8°C) water.  125°F (51.6°C) internal for more than 7 hours.  130°F (54.4°C) internal for 60 minutes.  135°F (57.2°C) internal for 3 minutes.  Above 135°F (57.2°C) internal instantaneous.	
		Cooking times and internal temperatures of meat products to achieve lethality	AMI Process Lethality Equation calculates f-values for individual processes based upon cooking and cooling times and temperatures.	
	B – <i>Salmonella</i> and <i>L. monocytogenes</i> survival during cooking process			Access AMI Process Lethality Equation at: <a href="http://www.amif.org/factsand.htm">http://www.amif.org/factsand.htm</a>



Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – <i>Salmonella</i> and <i>L. monocytogenes</i> survival during cooking process	Cooking cooked beef, roast beef, and cooked corned beef products	Time and temperature combinations to meet either a 6.5 or a 7.0 log reduction in <i>Salmonella</i> .	MPI Regulations, Section 318.17(a)  Appendix A to FSIS Compliance Guidelines  Access Appendix A, on internet at: <a href="http://www.fsis.usda.gov/oa/fr/95033f%2Da.htm">www.fsis.usda.gov/oa/fr/95033f%2Da.htm</a>
		Fully cooking ground beef patties	Fully cooked patties should reach an instantaneous internal temperature of 160°F (71°C).	MPI Regulations, Section 318.23(b)(1)(i)  Access on internet at:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301</a>
		Cooking cured and non-cured poultry products	Cooked, uncured poultry products should reach an instantaneous internal temperature of 160°F (71°C).  Cured and smoked poultry products should reach instantaneous internal 155°F (68°C).	MPI Regulations, Section 318.150(b)  Access on internet at:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301</a>



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Temperature control and storage after cooking	B- <i>Staphylococci aureus</i> , <i>Salmonella typhimurium</i> , and <i>Clostridium perfringens</i> growth during hot holding of roast beef	Fully cooked roast beef – holding temperature at 128°F (53.3°C)	When holding meat at 128°F (53.3°C) <i>Salmonella typhimurium</i> was reduced > 4 log units in 6 hours. <i>Clostridium perfringens</i> was reduced 2-3 log units, below detection limits in 6 hours.	Brown and Twedt 1972 cont'
	B – <i>Yersinia enterocolitica</i> growth	Storage of cooked beef, or pork roasts at 45°F (7°C)	<i>Y. enterocolitica</i> can increase 7 log units in 10 days at 45°F (7°C).	Hanna, M.O., J.C. Stewart, Z.L. Carpenter, D.L. Zink, C. Vanderzant. 1977. Development of <i>Yersinia enterocolitica</i> on raw and cooked beef and pork at different temperatures. Journal of Food Science. 42: 1180-1184.
	B – <i>Campylobacter jejuni</i> growth and survival	Store cooked ground chicken at 40°F (4°C)	<i>Campylobacter jejuni</i> decreased 1 to 2 log units over 17 days.	Blankenship, L.C., S.E. Craven. 1982. <i>Campylobacter jejuni</i> survival in chicken meat as a function of temperature. Applied and Environmental Microbiology. 44 (1) 88-92.
		Store cooked ground chicken at 73°F (23°C)	<i>Campylobacter jejuni</i> decreased 2.5 to 5 log units over 17 days.	
		Store cooked ground chicken at 99°F (37°C)	<i>Campylobacter jejuni</i> increased 1 to 2 log units over the first 4 days then decreased 1 log unit by day 17 for an over all 1 log unit change or no change.	
		Store cooked ground chicken at 109°F (43°C)	<i>Campylobacter jejuni</i> decreased 5 to 6 log units in 10 to 17 days.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – Growth of <i>Bacillus cereus</i> , <i>C. perfringens</i> , <i>E. coli</i> , <i>S. typhimurium</i> , and <i>S. aureus</i>	Chopped ham, sliced and vacuum packed, stored at 40°F (4°C) for 24 hours	There was no log change in <i>C. perfringens</i> , <i>E. coli</i> , <i>S. typhimurium</i> , and <i>S. aureus</i> , however, <i>B. cereus</i> 1.5 log units.	Stiles, M.E., L.-K. Ng. 1979. Fate of pathogens inoculated onto vacuum-packaged sliced hams to simulate contamination during packaging. Journal of Food Protection. 42 (6) 464-469..
		Chopped ham, sliced and vacuum packed, stored at 70°F (21°C) for 24 hours	<i>C. perfringens</i> decreased by 1 log units, the other pathogens tested all increased 0.5 to 3 log units.	
		Chopped ham, sliced and vacuum packed, stored at 86°F (30°C) for 24 hours	All pathogens tested increased 3.5 to 6.5 log units.	
		Chopped ham, sliced and vacuum packed, stored at 40°F (4°C) for 30 days	There was no log change in the pathogens tested except there was a 2 log unit decrease in <i>B. cereus</i> , and <i>C. perfringens</i> .	
		Chopped ham, sliced and vacuum packed, stored at 50°F (10°C) for 30 days	There was 1 to 2.5 log unit decreases in all pathogens tested except <i>E. coli</i> , which showed a 2.5 log growth.	
	B – Growth of <i>E. coli</i> , <i>S. typhimurium</i> , and <i>S. aureus</i>	Chopped ham, sliced and vacuum packed, stored at 40°F (4°C) for 24 hours	There was a 0.5 log decrease in <i>E. coli</i> , and <i>S. typhimurium</i> . There was no log change in <i>S. aureus</i> .	Stiles, M.E., and L.-K. Ng. 1979. Fate of enteropathogens inoculated onto chopped ham. Journal of Food Protection. 42 (8) 624-630.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – Growth of <i>E. coli</i> , <i>S. typhimurium</i> , and <i>S. aureus</i>	Chopped ham, sliced and vacuum packed, stored at 70°F (21°C) for 24 hours	There was a 2.5 log increase in <i>E. coli</i> , there was a 1 log increase in <i>S. typhimurium</i> , and a 1.5 to 3 log increase in <i>S. aureus</i> .	Stiles and Ng, 1979 cont'
		Chopped ham, sliced and vacuum packed, stored at 86°F (30°C) for 24 hours	There was a 2.5 log increase in <i>E. coli</i> , and <i>S. typhimurium</i> . There was greater than 6 log growth in <i>S. aureus</i> .	
	B – Growth of <i>S. typhimurium</i> , <i>S. aureus</i> , and <i>C. perfringens</i>	Cooked roast beef stored in air at 40°F (4.4°C) for 42 days	There was no log growth for <i>S. typhimurium</i> , <i>S. aureus</i> , or <i>C. perfringens</i> at 40°F (4.4°C) for up to 42 days.	Hintlian, C.B., and J.H. Hotchkiss. 1987. Comparative growth of spoilage and pathogenic organisms on modified atmosphere-packaged cooked beef. Journal of Food Protection. 50 (3) 218-223.
		Cooked roast beef stored in air at 40°F (4.4°C) for 0 to 35 days then at 55°F (12.8°C) for 7 days	There was >5 log increase for <i>S. typhimurium</i> , <i>S. aureus</i> , and <i>C. perfringens</i> after the 7 days at 55°F (12.8°C).	
		Cooked roast beef stored in 75% CO <sub>2</sub> , 10% O <sub>2</sub> , 15% N <sub>2</sub> at 40°F (4.4°C) for 42 days	There was no log growth for <i>S. typhimurium</i> , <i>S. aureus</i> , or <i>C. perfringens</i> at 40°F (4.4°C) for up to 42 days.	
		Cooked roast beef stored in 75% CO <sub>2</sub> , 10% O <sub>2</sub> , 15% N <sub>2</sub> at 40°F (4.4°C) for 0 to 35 days then at 55°F (12.8°C) for 7 days	There was >5 log increase for <i>S. typhimurium</i> , and 1 to 2 log increase of <i>S. aureus</i> and <i>C. perfringens</i> after the 7 days at 55°F (12.8°C).	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – growth of <i>Escherichia</i> , <i>Shigella</i> , <i>Proteus</i> , <i>Klebsiella</i> , <i>Bacillus</i> , and <i>Clostridium perfringens</i> ,	Water activity ( $a_w$ ) level at or below 0.95 such as some fresh meat, and cooked sausages, also foods containing approximately 40% sucrose or 7% NaCl	These pathogens will be inhibited at or below these water activity levels.	Beuchat, L.R. 1981. Microbial stability as affected by water activity. Cereal Foods World. 26 (7) 345-349.
	B – growth of <i>Salmonella</i> , <i>Vibrio</i> , <i>C. botulinum</i> , some molds and yeasts	Water activity ( $a_w$ ) level at or below 0.91 such as some cured meat, like hams, and foods containing 55% sucrose or 12% NaCl		
	B – <i>Listeria monocytogenes</i> , <i>Aeromonas hydrophila</i> , and <i>Yersinia enterocolitica</i> growth	Packaging sliced roast beef with controlled CO <sub>2</sub> atmosphere (saturated)	When packaged with a controlled CO <sub>2</sub> atmosphere there is less than 1 log unit of growth when stored at 29°F (-1.5°C) for 1,000 hours (>41 days).	Hudson J.A., S.J. Mott, and N. Penney. 1996. Growth of <i>Listeria monocytogenes</i> , <i>Aeromonas hydrophila</i> , and <i>Yersinia enterocolitica</i> on vacuum and saturated carbon dioxide controlled atmosphere-packaged sliced roast beef. Journal of Food Protection. 57 (3) 204-208.
		Vacuum packaging sliced roast beef	When vacuum packaged there is a 4 log growth when stored at 29°F (-1.5°C) for 1,000 hours (>41 days).	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – growth of mesophiles and psychrotrophs	Packaging roast beef with controlled CO <sub>2</sub> atmosphere (saturated)	Mesophiles and psychrotrophs grew 1.5 log units over 21 days.	McDaniel, M.C., J.A. Marchello, and A.M. Tinsley. 1984. Effect of different packaging treatments on microbiological and sensory evaluation of precooked beef roasts. Journal of Food Protection. 47 (81) 23-26.
		Packaging roast beef with controlled (15%) CO <sub>2</sub> and (30%) O <sub>2</sub> , (55%) N <sub>2</sub> atmosphere	Mesophiles grew 2.5 log units and psychrotrophs grew 4.5 log units over 21 days.	
		Vacuum packaging sliced roast beef	Mesophiles grew 4 log units and psychrotrophs grew 4.5 log units over 21 days.	
	B – <i>C. perfringens</i> , <i>S. aureus</i> , <i>E. coli</i> , <i>S. typhimurium</i> , and <i>L. monocytogenes</i> survival and growth on vacuum packaged roast beef	Cooked roast beef slices, vacuum packaged and stored at 37°F (3°C) for 70 days	Despite some decreases in counts (as much as 2 log units in some cases) <i>C. perfringens</i> , <i>S. aureus</i> , <i>E. coli</i> , <i>S. typhimurium</i> , and <i>L. monocytogenes</i> were detectable for the entire 70 days and a hazard is likely to occur if product is contaminated after cooking.	Michel, M.E., J.T. Keeton, and G.R. Acuff. 1991. Pathogen survival in precooked beef products in processing. Journal of Food Protection. 54 (10) 767-772.
	B – Growth of <i>S. aureus</i> , <i>Y. enterocolitica</i> , <i>B. cereus</i> , <i>S. typhimurium</i> and <i>S. enteritidis</i>	Sliced, vacuum-packaged bologna	<i>S. aureus</i> showed a 6 log growth over 28 days when stored at 54°F (12°C).	Nielsen, H.-J.S., and P. Zeuthen, 1984. Influence of lactic acid bacteria and the overall flora on development of pathogenic bacteria in vacuum-packed, cooked emulsion-style sausage. Journal of Food Protection. 48 (1) 28-34.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – Growth of <i>S. aureus</i> , <i>Y. enterocolitica</i> , <i>B. cereus</i> , <i>S. typhimurium</i> and <i>S. enteritidis</i>	Sliced, vacuum-packaged bologna	<i>S. aureus</i> showed a 1.5 log growth over 28 days when stored at 46°F (8°C).	Nielsen and Zeuthen. 1984, cont'
			<i>Y. enterocolitica</i> showed less than 2 log growth at 46°F (8°C) and less than 1 log growth at 41°F (5°C) over 28 days.	
			<i>S. typhimurium</i> showed a 4 log growth in 9 days when stored at 59°F (15°C).	
	B – Growth of <i>C. perfringens</i>	Cured hot dogs vacuum packaged	<i>B. cereus</i> and <i>S. enteritidis</i> does not grow at 50°F (10°C) or less.	
	B – <i>Listeria monocytogenes</i> survival and growth	Vacuum-packaged frankfurters stored 20 days at 40°F (4°C)	<i>C. perfringens</i> showed no growth over 28 days at 54°F (12°C), or 50°F (10°C).	
			<i>L. monocytogenes</i> multiplied > 1 log unit the first 10 days and another 1 log unit in the second 10 days. A hazard is likely due to the favorable environment the vacuum packaging creates.	Buncic, S., L. Paunovic, and D. Radisic. 1991. The fate of <i>Listeria monocytogenes</i> in fermented sausages and in vacuum-packaged frankfurters. Journal of Food Protection. 54 (6) 413-417.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – <i>Listeria monocytogenes</i> survival and growth	All-beef wiener exudate inoculated with 100 AU pediocin AcH, or 4 log units of <i>Pediococcus acidilactici</i> H stored at 40°F (4°C) for 29 days	<i>L. monocytogenes</i> decreased 1 to 2 log units with either of these treatments.	Yousef, A.E., J.B. Luchansky, A.J. Degnan, M.P. Doyle. 1991. Behavior of <i>Listeria monocytogenes</i> in wiener exudates in the presence of <i>Pediococcus acidilactici</i> H or Pediocin AcH during storage at 4 or 25°C. Applied and Environmental Microbiology. 57 (5) 1461-1467.
		All-beef wiener exudate stored at 40°F (4°C) for 29 days	<i>L. monocytogenes</i> decreased 0.61 to 3.8 log units in 29 days.	
		All-beef wiener exudate inoculated with 100 AU pediocin AcH, or 4 log units of <i>Pediococcus acidilactici</i> H stored at 77°F (25°C) for 5.8 days	<i>L. monocytogenes</i> decreased 3 to 4 log units with either of these treatments.	
		All-beef wiener exudate stored at 77°F (25°C) for 5.8 days	There was great variation in <i>L. monocytogenes</i> activity. pH < 4.4 = 2 to 4.2 log reduction. pH > 4.5 = 1.7 to 3.6 log increase.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – <i>C. perfringens</i> and <i>S. aureus</i> growth	Vacuum packaged cooked roast beef stored at 37°F (3°C) for 70 days	<i>C. perfringens</i> showed a 2 log decrease and <i>S. aureus</i> showed no log change in 70 days of storage.	Michel, M.E., J.T. Keeton, and G.R. Acuff. 1991. Pathogen survival in precooked beef products in processing. Journal of Food Protection. 54 (10) 767-772.
		Vacuum-packaged, cook-in-bag turkey pH 6, 0.3% sodium pyrophosphate and 1, 2, or 3% NaCl stored at 40°F (4°C)	There was no <i>C. perfringens</i> log increase at 40°F (4°C).	Juneja, V.K., and B.S. Marmer. 1996. Growth of <i>Clostridium perfringens</i> from spore inocula in sous-vide turkey products. Journal of International Food Microbiology. 32 (1-2) 115-123.
		Vacuum-packaged, cook-in-bag turkey pH 6, 0.3% sodium pyrophosphate and 1, 2, or 3% NaCl stored at 59°F (15°C)	There was no <i>C. perfringens</i> log increase at 59°F (15°C) with 3% NaCl for 28 days. However, 1 and 2 % NaCl showed 2 to 4 log increase over 28 days after the first 3 days when there was no growth.	
		Vacuum-packaged, cook-in-bag turkey pH 6, 0.3% sodium pyrophosphate and 1, 2, or 3% NaCl stored at 82°F (28°C)	There was no <i>C. perfringens</i> log increase at 82°F (28°C) for 8 hours, however in 28 days there was >5 log increase in all three formulations.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – <i>C. perfringens</i> growth	Vacuum-packaged beef goulash 1.6% NaCl, 5.5 pH, 1.5% or 3.0% sodium lactate or calcium lactate stored at 68°F (20°C)	<i>C. perfringens</i> grew >3 log units at 68°F (20°C) with sodium lactate, there was no log increase with calcium lactate.	Aran, N. 2001. The effect of calcium and sodium lactates on growth from spores of <i>Bacillus cereus</i> and <i>Clostridium perfringens</i> in a 'sous-vide' beef goulash under temperature abuse. International Journals of Food Microbiology. 63 (1-2) 117-123.
	B - <i>C. perfringens</i> and <i>B. cereus</i> growth	Vacuum-packaged beef goulash 1.6% NaCl, 5.5 pH, 1.5% or 3.0% sodium lactate or calcium lactate stored at 68°F (20°C)	There was no log increase of <i>B. cereus</i> in 28 days with 3% sodium lactate or 1.5% or 3% calcium lactate. There was a 1 log increase of <i>B. cereus</i> with 1.5% sodium lactate in 28 days. There was no log increase of <i>C. perfringens</i> with calcium lactate in 28 days however there was a 3 log increase when sodium lactate was used.	
		Vacuum-packaged beef goulash 1.6% NaCl, 5.5 pH, 1.5% or 3.0% sodium lactate or calcium lactate stored at 59°F (15°C)	There was no log increase of <i>B. cereus</i> in 28 days at 59°F (15°C). There was no log increase of <i>C. perfringens</i> when calcium lactate or 3% sodium lactate was used, however there was a 3 log increase when 1.5% sodium lactate was used.	



## **Heat Treated, Not Fully Cooked**

Includes: Char-marked patties, flash-fried products, bacon



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	C –Excessive nitrite level in product	Addition of preblended cure including sodium nitrite	“[If] using sodium nitrite diluted [to 6.25% by weight] with sodium chloride, which is received from the manufacturer with a continuing letter of guarantee, then acute nitrite toxicity is not a problem.” (due to self-limiting, high, salt concentration)	Borchert, L.L., and R. G. Cassens. 1998. Chemical hazard analysis for sodium nitrite in meat curing. American Meat Institute Foundation Paper. <a href="http://www.ag.ohio-state.edu/~meatsci/borca2.htm">http://www.ag.ohio-state.edu/~meatsci/borca2.htm</a>
		Addition of pure sodium nitrite	“Extreme caution must be exercised if pure sodium nitrite is used.” “The conservative estimate for a lethal dose in humans is 14 mg/kg, meaning the dose would be 1 g [(0.0022 lb)] for a 70 kg [(154 lb)] adult and 0.2 g [(8.8x10 <sup>-5</sup> lb)] for a 15 kg [(33 lb)] child.”	
		Addition of sodium nitrite	Sodium nitrite can be added up to 200 parts per million (or an equivalent of potassium nitrite) in the final product except in bacon where it can be added up to 120 ppm ingoing.	CFR 318.7(c)  To access on the internet:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301</a>



# **Not Heat Treated, Shelf Stable Process**

Includes: dry - cured products



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	C –Excessive nitrite level in product	Addition of preblended cure including sodium nitrite	“[If] using sodium nitrite diluted [to 6.25% by weight] with sodium chloride, which is received from the manufacturer with a continuing letter of guarantee, then acute nitrite toxicity is not a problem.” (due to self-limiting, high, salt concentration)	Borchert, L.L., and R. G. Cassens. 1998. Chemical hazard analysis for sodium nitrite in meat curing. American Meat Institute Foundation Paper. <a href="http://www.ag.ohio-state.edu/~meatsci/borca2.htm">http://www.ag.ohio-state.edu/~meatsci/borca2.htm</a>
		Addition of pure sodium nitrite	“Extreme caution must be exercised if pure sodium nitrite is used.” “The conservative estimate for a lethal dose in humans is 14 mg/kg, meaning the dose would be 1 g [(0.0022 lb)] for a 70 kg [(154 lb)] adult and 0.2 g [(8.8x10 <sup>-5</sup> lb)] for a 15 kg [(33 lb)] child.”	
		Addition of sodium nitrite	Sodium nitrite can be added up to 200 parts per million (or an equivalent of potassium nitrite) in the final product except in bacon where it can be added up to 120 ppm ingoing.	CFR 318.7(c)  To access on the internet:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301</a>
	B – Survival and growth of <i>Salmonella</i>	Addition of NaNO <sub>2</sub> and KNO <sub>3</sub> and use of starter culture or glucono-delta-lactone to lower pH to 4.8 to 5.3	100 ppm NaNO <sub>2</sub> and 150 ppm KNO <sub>3</sub> or 50 ppm NaNO <sub>2</sub> and 75 ppm KNO <sub>3</sub> is adequate to produce a safe dry sausage as long as a starter culture or glucono-delta-lactone is used to lower pH to 4.8 to 5.3.	Puolanne, E. 1977. Effects of reduced addition of nitrate and nitrite on the properties of dry sausage. Journal of the Scientific Agricultural Society of Finland. 49 (1) 1-106.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Fermentation	B - <i>E. coli</i> O157:H7 survival through fermentation and drying	Product is fermented, using starter culture, at 20-30 C, for 1-3 days, at about 90% RH, followed by drying for up to 60 days at about 85% RH.	Seven commercial processes were evaluated and it was found that fermentation can result in 0.3 to 1.3 log reduction of <i>E. coli</i> O157:H7; not sufficient to meet the required 2 log reduction. Three models have been developed to assist estimating the time required to achieve a 2 log reduction when parameters such as water activity, pH and drying time are used.	Pond, T.J., D.S. Wood, I.M. Mumin, S. Barbut and M.W. Griffith. 2001. Modeling the survival of <i>E. coli</i> O157:H7 in uncooked, semidry, fermented sausage. Journal of Food Protection. 64 (6) 759-766.
	B- Staphylococcal enterotoxin production	Using a starter culture to reduce meat pH.	Meat pH should decline to 5.0 within 12 hours, to prevent Staphylococcal enterotoxin production.	Good Manufacturing Practices for Fermented Dry and Semi-Dry Sausage Products, American Meat Institute Foundation, 1997.
	B – Potential Staphylococcus growth	Fermentation to pH 5.3 or less	<p>(Fermentation Temperature (°F)–60) X hours = degree hours</p> <p>Process acceptable if:</p> <p>Fewer than 1200 degree hours when the lowest fermentation temperature is less than 90°F (32°C).</p> <p>Fewer than 1000 degree hours when the highest fermentation temperature is between 90°F (32°C) and 100°F (38°C).</p> <p>Fewer than 900 degree hours when the highest fermentation temperature is greater than 100°F (38°C).</p>	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Drying	B – growth of many yeasts	Water activity ( $a_w$ ) level at or below 0.87 such as fermented sausage, and foods containing approximately 65% sucrose or 15%NaCl	These pathogens are inhibited at these water activity levels.	Beuchat, L.R. 1981. Microbial stability as affected by water activity. Cereal Foods World. 26 (7) 345-349.
	B – growth of most molds (mycogenic penicillia), <i>Staphylococcus aureus</i> , most <i>Saccharomyces (bailii) spp.</i> <i>Debaromyces</i>	Water activity ( $a_w$ ) level at or below 0.80	These pathogens are inhibited at these water activity levels.	
	B – growth of halophilic bacteria, <i>mycotoxigenic aspergilli</i>	Water activity ( $a_w$ ) level at or below 0.75		
Storage	B – <i>Staphylococcus</i> growth	Storage of dry-cured hams at 36°F (2°C) in vacuum packaging.	A hazard by <i>Staphylococcus</i> is less likely if stored just above freezing.	Kemp, J.D., B.E. Langlois, K. Akers, and D.K. Aaron. 1989. Effect of storage temperature, time and method of slicing on microbial population and white film development in vacuum packaged, dry-cured ham slices. Journal of Food Science. 54 (4) 871-873.
		Storage of dry-cured hams at 75°F (24°C) in vacuum packaging.	A bacterial hazard is likely to occur because there are no retardant conditions to slow bacteria growth. There is a 3 to 4 log increase in growth from storage at 36°F (2°C).	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – <i>E. coli</i> O157:H7 growth in ground beef product	Ground beef dried at 72°F (22°C) to near 30% moisture when stored at 40°F (4°C) 55% relative humidity for 2 months, <b>NOT</b> vacuum packaged	No hazard is posed after 2 months, in these conditions as all traces of <i>E. coli</i> were destroyed.	Cosanu, S., and K. Ayhan. 2000. Survival of enterohaemorrhagic <i>Escherichia coli</i> O157:H7 strand in Turkish soudjouck during fermentation, drying and storage periods. Meat Science. 54 (4) 407-411.
	B – <i>E. coli</i> O157:H7 growth in ground beef product	Ground beef dried at 72°F (22°C) to near 30% moisture when stored at 40°F (4°C) 55% relative humidity for 3 months, vacuum packaged	No hazard is posed after 3 months of storage in these conditions as all traces of <i>E. coli</i> were destroyed.	
	B- Survival of <i>E. coli</i> O157:H7, <i>Listeria monocytogenes</i> , <i>Salmonella</i> spp. and <i>Staphylococcus aureus</i> .	Sliced, vacuum-packaged dry-cured ham stored at 77°F (25°C) for 28 days	Survival of these pathogens in vacuum-packaged dry-cured ham may pose a hazard if consumed without adequate cooking.	Ng, W.F., BE. Langlois, and W.G. Moody. 1997. Fate of selected pathogens in vacuum-packaged dry-cured (country style) ham slices stored at 2 and 25°C. Journal of Food Protection. 60 (12) 1541-1547.
		Sliced, vacuum-packaged dry-cured ham stored at 35.6°F (2°C) for 28 days	Survival of these pathogens in vacuum-packaged dry-cured ham may pose a hazard if consumed without adequate cooking.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B - <i>E. coli</i> O157:H7 survival, and growth	After fermentation at 76°F (24°C), 90% RH to pH <4.8, then dried at 55°F (13°C) 65% RH to pH approx. 4.6, $a_w$ approx. 0.92, 4.41% salt, 44.5% moisture, M/Pr ratio of greater than 1.9:1, sealed in oxygen impermeable bags with air, or vacuum sealed, stored at 40°F (4°C)	After 90 days of storage at 40°F (4°C), <i>E. coli</i> O157:H7 was still detectable.	Faith, N.G., N. Parniere, T. Larson, T.D. Lorang, C.W. Kaspar, and J.B. Luchansky. 1998. Viability of <i>Escherichia coli</i> O157:H7 in salami following conditioning of batter, fermentation and drying of sticks and storage of slices. Journal of Food Protection. 61 (4) 377-382.
	B - <i>E. coli</i> O157:H7 survival, and growth	After fermentation at 76°F (24°C), 90% RH to pH <4.8, then dried at 55°F (13°C) 65% RH to pH approx. 4.6, $a_w$ approx. 0.92, 4.41% salt, 44.5% moisture, M/Pr ratio of greater than 1.9:1, sealed in oxygen impermeable bags with air, or vacuum sealed, stored at 70°F (21°C)	After 90 days of storage at 70°F (21°C) no <i>E. coli</i> O157:H7 was detectable by direct plating but was found after enrichment.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Aging time and packaging	B – growth of bacteria and mold	Curing hams for 2 days per pound covered with stockinettes	Bacteria and molds are equally likely to grow with either type of packaging, which could potentially cause a hazard.	Draughon, F.A., C.C. Melton, and D. Maxedon. 1981. Microbial profiles of country-curd hams aged in stockinettes, barrier bags and paraffin wax. Applied and Environmental Microbiology. 41 (4) 1078-1080.
		Curing hams for 2 days per pound covered with barrier bags		
	B – growth of bacteria and mold	Curing hams for 2 days per pound covered with a coating of paraffin wax	The use of paraffin wax coating did not seem to affect the growth of bacteria, however molds were less likely to grow, reducing the risk of mycotoxins.	
	B – survival of <i>Trichina spiralis</i>	Curing dry-cured ham at 50°F (10°C) for at least 90 days	Trichina are rendered non infective when ham is cured at the given time temperature intervals.	Lin, K.W., J.T. Keeton, T.M. Craig, R.H. Huey, M.T. Longnecker, H.R. Gamble, C.S. Custer, and H.R. Cross. 1990. Bioassay of dry-cured ham processed to affect <i>Trichina spiralis</i> . Journal of Food Science. 55 (2) 289-292, 297.
		Curing dry-cured ham at 75°F (23.9°C) for at least 35 days		
		Curing dry-cured ham at 90°F (32.2°C) for at least 11 days		



# **Heat Treated, Shelf Stable Process**

Includes: dry sausage products



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	C –Excessive nitrite level in product	Addition of preblended cure including sodium nitrite	“[If] using sodium nitrite diluted [to 6.25% by weight] with sodium chloride, which is received from the manufacturer with a continuing letter of guarantee, then acute nitrite toxicity is not a problem.” (due to self-limiting, high, salt concentration)	Borchert, L.L., and R. G. Cassens. 1998. Chemical hazard analysis for sodium nitrite in meat curing. American Meat Institute Foundation Paper. <a href="http://www.ag.ohio-state.edu/~meatsci/borca2.htm">http://www.ag.ohio-state.edu/~meatsci/borca2.htm</a>
		Addition of pure sodium nitrite	“Extreme caution must be exercised if pure sodium nitrite is used.” “The conservative estimate for a lethal dose in humans is 14 mg/kg, meaning the dose would be 1 g [(0.0022 lb)] for a 70 kg [(154 lb)] adult and 0.2 g [(8.8x10 <sup>-5</sup> lb)] for a 15 kg [(33 lb)] child.”	
		Addition of sodium nitrite	Sodium nitrite can be added up to 200 parts per million (or an equivalent of potassium nitrite) in the final product except in bacon where it can be added up to 120 ppm ingoing.	CFR318.7(c)  To access on the internet:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301</a>
	B – <i>Listeria monocytogenes</i> , survival with potassium nitrate and/or sodium nitrite addition	Addition of sodium nitrite at 50 ppm (3-3.5% NaCl) to dried sausage	<i>Listeria monocytogenes</i> can be reduced by 1 log unit over a period of 21 days of storage.	Junttila, J., J. Hirn, P. Hill, and E. Nurmi. 1989. Effect of different levels of nitrite and nitrate on the survival of <i>Listeria monocytogenes</i> during the manufacture of fermented sausage. Journal of Food Protection. 52 (3) 158-161.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – <i>Listeria monocytogenes</i> , survival with potassium nitrate and/or sodium nitrite addition	Addition of sodium nitrite at 120 ppm (3-3.5% NaCl) to dried sausage	<i>Listeria monocytogenes</i> can be reduced by 1 log unit over a period of 21 days of storage.	Junttila et al. 1989 cont'
		Addition of sodium nitrite at 200 ppm (3-3.5% NaCl) to dried sausage	<i>Listeria monocytogenes</i> can be reduced by 1 log unit over a period of 21 days of storage. However this is over the limit of allowable nitrite.	
		Addition of sodium nitrite at 200 ppm and potassium nitrate at 300 ppm (3% NaCl) to dried sausage	<i>Listeria monocytogenes</i> can be reduced by 2 log units over a period of 21 days of storage. However this is over the limit of allowable nitrite.	
		Addition of potassium nitrate at 1000 ppm (3.5% NaCl) to dried sausage	<i>Listeria monocytogenes</i> can be reduced by 3 log units over a period of 21 days of storage. However this is over the limit of allowable nitrite.	
	B – Survival and growth of <i>Salmonella</i>	Addition of NaNO <sub>2</sub> and KNO <sub>3</sub> and use of starter culture or glucono-delta-lactone to lower pH to 4.8 to 5.3	100 ppm NaNO <sub>2</sub> and 150 ppm KNO <sub>3</sub> or 50 ppm NaNO <sub>2</sub> and 75 ppm KNO <sub>3</sub> is adequate to produce a safe dry sausage as long as a starter culture or glucono-delta-lactone is used to lower pH to 4.8 to 5.3.	Puolanne, E. 1977. Effects of reduced addition of nitrate and nitrite on the properties of dry sausage. Journal of the Scientific Agricultural Society of Finland. 49 (1) 1-106.



Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B –, <i>S. aureus</i> , <i>Salmonella</i> and <i>Clostridium sporogenes</i> survival with nitrite addition	Addition of up to 150 ppm of nitrite	Nitrite at these levels has little or no effect controlling <i>Staphylococcus aureus</i> (1-2 log growth), <i>Salmonella</i> (0.5 – 1 log reduction), or <i>Clostridium sporogenes</i> (no log change).	Collins-Thompson, D.L., B. Krusky, W.R. Osborne, and A.H.W. Hauschild. 1984. The effect of nitrite on the growth of pathogens during manufacture of dry and semi-dry sausage. Canadian Institute of Food Science and Technology Journal. 17 (2) 102-106.
	B – <i>L. monocytogenes</i> heat resistance	Holding product between 104°F (40°C) and 118°F (48°C) for 3 to 20 minutes	D-value for <i>L. monocytogenes</i> increases up to 2.3 fold when cooked at 131°F (55°C). The time allotted to destroy <i>L. monocytogenes</i> must increase correspondingly.	Linton, R.H., M.D. Pierson, and J.R. Bishop. 1990. Increase in heat resistance of <i>Listeria monocytogenes</i> Scott A by sublethal heat shock. Journal of Food Protection. 53 (11) 924-927.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Processing	B - <i>E. coli</i> O157:H7 survival, and growth	Tempering meat mixture containing starter culture at 55°F (13°C) for less than 2 hours, then freezing at -4°F (-20°C) for more than 3 days, and thawing at 40°F (4°C) over a period of at least 3 days followed by fermentation at 76°F (24°C), 90%RH to pH at or less than 4.8, then drying at 55°F (13°C)	Tempering meat or directly freezing then thawing at 40°F (4°C) over 3 days prior to fermentation and drying does not effect <i>E. coli</i> O157:H7 survival during storage at either 40°F (4°C) or 70°F (21°C). <i>E. coli</i> O157:H7 was reduced 0.9 to 1.5 log units during fermentation and 0.2 to 0.6 log units during drying.	Faith, N.G., N. Parniere, T. Larson, T.D. Lorang, C.W. Kaspar, and J.B. Luchansky. 1998. Viability of <i>Escherichia coli</i> O157:H7 in salami following conditioning of batter, fermentation and drying of sticks and storage of slices. Journal of Food Protection. 61 (4) 377-382.
		Freeze meat mixture containing starter culture at -4°F (-20°C) >3 days then thawing at 40°F (4°C) over a period of at least 3 days followed by fermentation at 76°F (24°C), 90%RH to pH at or less than 4.8, then drying at 55°F (13°C)		



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Processing	B - <i>E. coli</i> O157:H7 survival, and growth	Refrigerate meat mixture containing starter culture less than 8 hours at 40°F (4°C) followed by fermentation at 76°F (24°C), 90%RH to pH at or less than 4.8, then drying at 55°F (13°C)	Tempering meat or directly freezing then thawing at 40°F (4°C) over 3 days prior to fermentation and drying does not effect <i>E. coli</i> O157:H7 survival during storage at either 40°F (4°C) or 70°F (21°C). <i>E. coli</i> O157:H7 was reduced 0.9 to 1.5 log units during fermentation and 0.2 to 0.6 log units during drying.	Faith et al. 1998 cont'
	B – <i>E. coli</i> O157:H7 survival through drying	Pork and beef pepperoni fermented at 96°F (35.5°C), 85% RH and 5.0 pH or less, then dried at 55°F (13°C), 65% RH to a moisture, protein ration of 1.6:1	<i>E. coli</i> O157:H7 was reduced 1.2 log units with this process.	Hinkins, J.C., N.G. Faith, T.D. Lorang, P. Bailey, D. Buege, C.W. Kaspar, and J.B. Luchansky. 1996. Validation of pepperoni processes for control of <i>Escherichia coli</i> O157:H7. Journal of Food Protection 59 (12) 1260-1266.



## Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Processing	B – <i>E. coli</i> O157:H7 survival through drying	Pork and beef pepperoni fermented at 96°F (35.5°C), 85% RH and 5.0 pH or less, heated to 128°F (53°C) for 60 minutes or 145°F (63°C) instantaneous, then dried at 55°F (13°C), 65% RH to a moisture, protein ration of 1.6:1	This processing decreased the counts of <i>E. coli</i> O157:H7, 5 log units or more, and did not visibly affect the texture or appearance of the product.	Hinkins et al. 1996 cont'
Fermentation	B – <i>L. monocytogenes</i> survival and growth	Fermented pork and beef sausages, ripened for 4 days at 64-68°F (18-20°C) then dried at 64°F (18°C) with a pH range of 5.47 to 4.8	<i>L. monocytogenes</i> decrease 3 log units in 35 days.	Buncic, S., L. Paunovic, and D. Radisic. 1991. The fate of <i>Listeria monocytogenes</i> in fermented sausages and in vacuum-packaged frankfurters. Journal of Food Protection. 54 (6) 413-417.
		Beef and pork sausage fermented at 32°F (90°C) without a starter culture	<i>L. monocytogenes</i> increased 2 log units during fermentation.	Glass, K.A., and M.P. Doyle. 1989. Fate and thermal inactivation of <i>Listeria monocytogenes</i> in beaker sausage and pepperoni. Journal of Food Protection 52 (4) 226-231, 235.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Fermentation	B – <i>L. monocytogenes</i> survival and growth	Beef and pork sausage fermented at 32°F (90°C) with a lactic starter culture ( <i>Pediococcus acidilactici</i> )	<i>L. monocytogenes</i> failed to grow during fermentation and was reduced by 1-2 log units.	Glass and Doyle 1989 cont'
		Salami product (2.5% NaCl, 250 ppm KNO <sub>3</sub> 0.3% sucrose) using a bacteriocin producing strain of <i>Lactobacillus plantarum</i>	Bacteriocin producing lactic acid bacteria will prevent growth and survival of <i>L. monocytogenes</i> .	Campanini, M., I. Pedrazzoni, S. Barbuti, and P. Baldini. 1993. Behavior of <i>Listeria monocytogenes</i> during the maturation of naturally and artificially contaminated salami: effect of lactic-acid bacteria starter cultures. International Journal of Food Microbiology. 20 (3) 169-175.
		Salami product (2.5% NaCl, 250 ppm KNO <sub>3</sub> 0.3% sucrose) using a unknown starter culture	Unknown starter cultures or known cultures that do not produce bacteriocin will prevent the growth of <i>L. monocytogenes</i> but will not destroy contamination.	
	B – B - <i>E. coli</i> O157:H7 survival through fermentation and drying	Product is fermented, using starter culture, at 20-30 C, for 1-3 days, at about 90% RH, followed by drying for up to 60 days at about 85% RH	Seven commercial processes were evaluated and it was found that fermentation can result in 0.3 to 1.3 log reduction of <i>E. coli</i> O157:H7; not sufficient to meet the required 2 log reduction. Three models have been developed to assist estimating the time required to achieve a 2 log reduction when parameters such as water activity, pH and drying time are used.	Pond, T.J., D.S. Wood, I.M. Mumin, S. Barbut and M.W. Griffith. 2001. Modeling the survival of <i>E. coli</i> O157:H7 in uncooked, semidry, fermented sausage. Journal of Food Protection. 64 (6) 759-766.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Fermentation	B – B - <i>E. coli</i> O157:H7 survival through fermentation and drying	Pork and beef pepperoni fermented at 96°F (35.5°C), 85% RH and 5.0 pH or less, then dried at 55°F (13°C), 65% RH to a moisture, protein ration of 1.6:1	This processing decreased the counts of <i>E. coli</i> O157:H7, 1.2 log units.	Hinkins, J.C., N.G. Faith, T.D. Lorang, P. Bailey, D. Buege, C.W. Kaspar, and J.B. Luchansky. 1996. Validation of pepperoni processes for control of <i>Escherichia coli</i> O157:H7. Journal of Food Protection. 59 (12) 1260-1266.
		Pork and beef pepperoni fermented at 96°F (35.5°C), 85% RH and 5.0 pH or less, heated to 128°F (53°C) for 60 minutes or 145°F (63°C) instantaneous, then dried at 55°F (13°C), 65% RH to a moisture, protein ration of 1.6:1	This processing decreased the counts of <i>E. coli</i> O157:H7, 5 log units or more, and did not visibly affect the texture or appearance of the product.	
	B- Staphylococcal enterotoxin production	Using a starter culture to reduce meat pH	Meat pH should decline to 5.0 within 12 hours, to prevent Staphylococcal enterotoxin production.	Good Manufacturing Practices for Fermented Dry and Semi-Dry Sausage Products, American Meat Institute Foundation, 1997.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Fermentation	B – Potential <i>Staphylococcus</i> growth	Fermentation to pH 5.3 or less	<p>(Fermentation Temperature (°F) – 60) X hours = degree hours</p> <p>Process acceptable if:</p> <p>Fewer than 1200 degree hours when the lowest fermentation temperature is less than 90°F (32°C).</p> <p>Fewer than 1000 degree hours when the highest fermentation temperature is between 90°F (32°C) and 100°F (38°C).</p> <p>Fewer than 900 degree hours when the highest fermentation temperature is greater than 100°F (38°C).</p>	GMP's 1997, cont'
	B - Survival of <i>Salmonella seftenberg</i> , <i>C. perfringens</i> , and <i>E. coli</i> O128:B12	Dried fermented turkey sausage step-wise heat treated at 81°F (27°C) for 3 hours, 90°F (32°C) for 4 hours, 115°F (46°C) for 5 hours, spray cooled to 61 to 64°F (16 to 18°C) and dried at 50°F (10°C) 72% RH for 8 days	<p><i>S. seftenberg</i> decreased 1.5 to 20 log units</p> <p><i>C. perfringens</i> decreased 2 to 3.6 log units</p> <p><i>E. coli</i> O128:B12 decreased 1.4 to 2.1 log units.</p>	Baran, W.L., and K.E. Stevenson. 1975. Survival of selected pathogens during processing of a fermented turkey sausage. Journal of Food Science. 40 (3) 618-620.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Heat Treatment	B – Growth and survival of <i>L. monocytogenes</i>	Hold product that has been fermented at 90°F (32°C) for 10 hours at 90°F (32°C)	After 10 hours there was greater than 1 log reduction of <i>L. monocytogenes</i> . Final results were below level of detection.	Glass, K.A., and M.P. Doyle. 1989. Fate and thermal inactivation of <i>Listeria monocytogenes</i> in beaker sausage and pepperoni. Journal of Food Protection 52 (4) 226-231, 235.
	B – Growth and survival of <i>L. monocytogenes</i>	Hold product that has been fermented at 90°F (32°C) for 8 hours at 115°F (46°C) after reaching that as the internal temperature	After 8 hours there was greater than 2 log reduction of <i>L. monocytogenes</i> . Final results were below level of detection.	
		Hold product that has been fermented at 90°F (32°C) for 8 hours at 125°F (52°C) after reaching that as the internal temperature		
		Hold product that has been fermented at 90°F (32°C) for 4 hours at 135°F (57°C) after reaching that as the internal temperature	After 4 hours there was greater than 2 log reduction of <i>L. monocytogenes</i> . Final results were below level of detection.	



## Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Heat Treatment	B – Growth and survival of <i>L. monocytogenes</i>	Hold product that has been fermented at 90°F (32°C) for 4 hours at 145°F (63°C) after reaching that as the internal temperature	After 4 hours there was greater than 2 log reduction of <i>L. monocytogenes</i> . Final results were below level of detection.	Glass and Doyle 1998 cont'
		Beef and pork sausage to at least 125°F (51.7°C) for 4 hours	When heated to at least 125°F (51.7°C) and held for 4 hours there was a 5 log reduction of <i>L. monocytogenes</i> .	
Drying	B – <i>S. aureus</i> growth	Water activity level 0.92-0.91, at 77°F (25°C) in salami	<i>S. aureus</i> growth is not inhibited when pH 6.0 or higher and a hazard is especially possible at $a_w$ 0.92-0.91 because of a lack of competing flora. When pH is 5.0 or lower a 6 log unit reduction was found after 21 days.	Martinez, E.J., N. Bonino, and S.M. Alzamora. 1986. Combined effect of water activity, pH and additives on growth of <i>Staphylococcus aureus</i> in model salami systems. Food Microbiology. 3 (4) 321-329.
		Water activity level 0.90 or less, at 77°F (25°C) in salami	The pH is not a factor in <i>S. aureus</i> growth, and a hazard is not likely.	
	B – growth of many yeasts	Water activity ( $a_w$ ) level at or below 0.87 such as fermented sausage, and foods containing approximately 65% sucrose or 15%NaCl	These pathogens are inhibited at these water activity levels.	Beuchat, L.R. 1981. Microbial stability as affected by water activity. Cereal Foods World. 26 (7) 345-349.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Drying	B – growth of most molds (mycogenic penicillia), <i>Staphylococcus aureus</i> , most <i>Saccharomyces(ba ilii) spp.</i> <i>Debaromyces</i>	Water activity ( $a_w$ ) level at or below 0.80	These pathogens are inhibited at these water activity levels.	Beuchat, 1981, cont'
	B – growth of halophilic bacteria, <i>mycotoxigenic aspergilli</i>	Water activity ( $a_w$ ) level at or below 0.75		
Packaging and Storage	B - <i>E. coli</i> O157:H7 survival, and growth	After fermentation at 76°F (24°C), 90% RH to pH <4.8, then dried at 55°F (13°C) 65% RH to pH approx. 4.6, $a_w$ approx. 0.92, 4.41% salt, 44.5% moisture, M/Pr ratio of greater than 1.9:1, sealed in oxygen impermeable bags with air, or vacuum sealed, stored at 40°F (4°C)	After 90 days of storage at 40°F (4°C), <i>E. coli</i> O157:H7 was still detectable.	Faith, N.G., N. Parniere, T. Larson, T.D. Lorang, C.W. Kaspar, and J.B. Luchansky. 1998. Viability of <i>Escherichia coli</i> O157:H7 in salami following conditioning of batter, fermentation and drying of sticks and storage of slices. Journal of Food Protection. 61 (4) 377-382.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and Storage	B - <i>E. coli</i> O157:H7 survival, and growth	After fermentation at 76°F (24°C), 90% RH to pH <4.8, then dried at 55°F (13°C) 65% RH to pH approx. 4.6, a <sub>w</sub> approx. 0.92, 4.41% salt, 44.5% moisture, M/Pr ratio of greater than 1.9:1, sealed in oxygen impermeable bags with air, or vacuum sealed, stored at 70°F (21°C)	After 90 days of storage at 70°F (21°C) no <i>E. coli</i> O157:H7 was detectable by direct plating but was found after enrichment.	Faith et al. 1998 cont'



## **Secondary Inhibitors, Not Shelf Stable Process**

Includes: uncooked corned beef and cured pork



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	C –Excessive nitrite level in product	Addition of preblended cure including sodium nitrite	“[If] using sodium nitrite diluted [to 6.25% by weight] with sodium chloride, which is received from the manufacturer with a continuing letter of guarantee, then acute nitrite toxicity is not a problem.” (due to self-limiting, high, salt concentration)	Borchert, L.L., and R. G. Cassens. 1998. Chemical hazard analysis for sodium nitrite in meat curing. American Meat Institute Foundation Paper. <a href="http://www.ag.ohio-state.edu/~meatsci/borca2.htm">http://www.ag.ohio-state.edu/~meatsci/borca2.htm</a>
		Addition of pure sodium nitrite	“Extreme caution must be exercised if pure sodium nitrite is used.” “The conservative estimate for a lethal dose in humans is 14 mg/kg, meaning the dose would be 1 g [(0.0022 lb)] for a 70 kg [(154 lb)] adult and 0.2 g [(8.8x10 <sup>-5</sup> lb)] for a 15 kg [(33 lb)] child.”	
		Addition of sodium nitrite	Sodium Nitrite can be added up to 200 parts per million (or an equivalent of potassium nitrite) in the final product except in bacon where it can be added up to 120 ppm ingoing.	CFR 318.7(c)  To access on the internet: <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301</a>
Fermentation	B – <i>S. aureus</i> growth	Country-style hams (60% sucrose and 38% salt) with lactic acid bacteria added	When inoculated with lactic acid bacteria, Staphylococcal growth was inhibited.	Bartholomew, D.T., and T.N. Blumer. 1980. Inhibition of <i>Staphylococcus</i> by lactic acid bacteria in country-style hams. Journal of Food Science. 45 (3) 420-425, 430.



# **Irradiation**

This information crosses many process categories.

There is information in this section that has not been approved for use as of publication time,  
however it is included for future reference.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Irradiation	B – <i>Salmonella</i> survival	Irradiating mechanically deboned poultry with 0.75 to 3.00 kGy at 32°F (0°C)	Irradiating at 32°F (0°C), 0.75 kGy resulted in a 1 log decrease of <i>Salmonella</i> . 1.5 kGy resulted in a 3 log reduction, 2.25 kGy resulted in a 5 log reduction and 3.0 kGy resulted in a 7 to 8 log reduction.	Thayer, D.W. 1995. Use of irradiation to kill enteric pathogens on meat and poultry. Journal of Food Safety. 15 (2) 181-192.
		Irradiating mechanically deboned poultry with 0.75 to 3.00 kGy at 32°F (0°C) then cooking to an internal temperature of 140°F (60°C) for 2 minutes	Irradiating at 32°F (0°C) followed by cooking to 140°F (60°C) for 2 minutes, 0.75 kGy resulted in a 6 log decrease of <i>Salmonella</i> . 1.5 kGy to 3.0 kGy resulted in a 9 log reduction.	
	B – <i>S. typhimurium</i> survival	Irradiating mechanically deboned chicken with 0.75 to 3.0 kGy then heated for 2.0 minutes at 140°F (60°C)	The heat treatment after irradiation destroys 6 log units more than just irradiation at 1.5 kGy, and provides the same destruction as the irradiation increases.	Radomyski, T., E.A. Murano, D.G. Olson, P.S. Murano. 1994. Elimination of pathogens of significance in food by low-dose irradiation: a review. Journal of Food Protection. 57 (1) 73-86.
	B – <i>Campylobacter jejuni</i> survival	Irradiating chicken carcasses with 2.5 kGy at 37.4 to 38.3°F (3 to 3.5°C)	<i>Campylobacter</i> is reduced by 4.19 log units, and remained at least 2.5 log units lower than non-irradiated carcasses when stored at 40°F (4°C) for 18 days.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Irradiation	B – <i>C. botulinum</i> survival and toxin production	Irradiated fresh pork with 1 kGy packaged with 10% to 20% oxygen stored at 59°F (15°C) for 14 days	Both irradiated and non-irradiated products were toxic after 14 days.	Radomyski et al. cont'
		Irradiated fresh pork with 1 kGy packaged with 0% oxygen stored at 59°F (15°C) for 43 days	Irradiated pork showed no toxicity for 43 days while non-irradiated pork showed toxicity after 21 days.	
	B – <i>Escherichia coli</i> O157:H7 survival	Irradiation of ground beef at 1.5 kGy <i>in vacuo</i> at temperatures ranging from –76°F (–60°C) to 59°F (15°C)	1.5 kGy irradiation at temperatures ranging from –76°F (–60°C) to –4°F (–20°C) resulted in a 1 to 2 log reduction of <i>E. coli</i> O157:H7. 1.5 kGy irradiation at temperatures ranging from 32°F (0°C) to 59°F (15°C) resulted in a 4 to 5 log reduction of <i>E. coli</i> O157:H7.	Thayer, D.W. 1995. Use of irradiation to kill enteric pathogens on meat and poultry. Journal of Food Safety. 15 (2) 181-192.
	B – <i>Escherichia coli</i> O157:H7 survival	Irradiation of raw ground beef at 4.5 kGy refrigerated and 7.0 kGy frozen	A maximum dosage of 4.5 kGy is allowed to control <i>E. coli</i> 157:H7 on refrigerated raw meat and 7.0 kGy when the meat is frozen	CFR 179.26  Access on the internet at:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/21cfrv3_99.html">http://www.access.gpo.gov/nara/cfr/waisidx_99/21cfrv3_99.html</a>



Irradiation

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Irradiation	B – <i>Escherichia coli</i> O157:H7 survival	Irradiating raw mechanically deboned chicken meat or ground beef vacuum packaged or with air with 0.27 kGy to 0.42 kGy at temperatures between 41°F (5°C) and 23°F (-5°C)	<i>E. coli</i> O157:H7 is reduced 1 log unit with this treatment.	Thayer, D.W., and G. Boyd. 1993. Elimination of <i>Escherichia coli</i> O157:H7 in meats by gamma irradiation. Applied and Environmental Microbiology. 59 (4) 1030-1034.
		Irradiating vacuum packaged raw ground beef with 0.75 kGy to 3.0 kGy at 32°F (0°C) then stored at 95°F (35°C) for 20 hours	<i>E. coli</i> O157:H7 was reduced to less than 10 CFU/g (a 4.8 log reduction) and after 20 hours at 95°F (35°C) no verotoxin was detected.	
	B – <i>Trichinella spiralis</i> survival	Irradiation of ground pork	A minimum dose of 0.3 kGy and a maximum dose of 1 kGy is allowed to destroy <i>Trichinella spiralis</i> .	CFR 179.26  Access on the internet at:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/21cfrv3_99.html">http://www.access.gpo.gov/nara/cfr/waisidx_99/21cfrv3_99.html</a>



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Irradiation	B – <i>Salmonella</i> survival	Irradiation of ground poultry	A maximum dose of 3 kGy is allowed to control <i>Salmonella</i> on raw poultry meat not excluding oxygen from the package.	CFR 179.26  Access on the internet at:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/21cfrv3_99.html">http://www.access.gpo.gov/nara/cfr/waisidx_99/21cfrv3_99.html</a>
	B – <i>L. monocytogenes</i> and <i>Salmonella</i> survival after irradiation	Irradiating raw and cooked hams and pork chops with 2.0 kGy and storage at 45°F (7°C) for 7 days and 2 days at 77°F (25°C)	2.0 kGy will reduce <i>L. monocytogenes</i> and <i>Salmonella</i> 6 log units, however after 7 days and storage at 45°F (7°C), then storage for 2 days at 77°F (25°C) shows a 5 log growth.	Fu, A.H., J.G. Sebranek, and E.A. Murano. 1995. Survival of <i>Listeria monocytogenes</i> and <i>Salmonella typhimurium</i> and quality attributes of cooked pork chops and ham after irradiation. Journal of Food Science. 60 (5) 1001-1005, 1008.
		Irradiating hams and pork chops with .75 kGy and storage at 45°F (7°C) and 2 days at 77°F (25°C) NOTE: Irradiation of ham products is currently not permitted by USDA/FSIS	0.75 kGy will reduce <i>L. monocytogenes</i> and <i>Salmonella</i> 2 log units, however after 7 days and storage at 45°F (7°C), then storage for 2 days at 77°F (25°C) shows a 5 log growth.	



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Irradiation	B – <i>L. monocytogenes</i> and <i>S. aureus</i> survival	Irradiating ground beef at 0.5 kGy	This treatment will result in 0.82 log reduction of <i>L. monocytogenes</i> and 1.10 log reduction of <i>S. aureus</i> .	Monk, J.D. M.A. Rocelle, S. Clavero, L.R. Beuchat, M.P. Doyle, and R.E. Brackett. 1994. Irradiation inactivation of <i>Listeria monocytogenes</i> and <i>Staphylococcus aureus</i> in low- and high-fat, frozen and refrigerated ground beef. Journal of Food Protection. 57 (11) 969-974.
		Irradiating ground beef at 1.0 kGy	This treatment will result in 1.64 log reduction of <i>L. monocytogenes</i> and 2.21 log reduction of <i>S. aureus</i> .	
		Irradiating ground beef at 1.5 kGy	This treatment will result in 2.46g reduction of <i>L. monocytogenes</i> and 3.11 log reduction of <i>S. aureus</i> .	
		Irradiating ground beef at 2.0 kGy	This treatment will result in 3.28 log reduction of <i>L. monocytogenes</i> and 4.42 log reduction of <i>S. aureus</i> .	
		Irradiating ground beef at 2.5 kGy	This treatment will result in 4.10 log reduction of <i>L. monocytogenes</i> and 5.12 log reduction of <i>S. aureus</i> .	
	B – <i>L. monocytogenes</i> survival	Irradiating ground pork with 0.25 to 1.25 kGy at room temperature.	<i>L. monocytogenes</i> was reduced 3 log units.	Tarté, R.R., E.A, Murano, D.G. Olson. 1996. Survival and injury of <i>Listeria monocytogenes</i> , <i>Listeria innocua</i> , and <i>Listeria ivanovii</i> in ground pork following electron beam irradiation. Journal of Food Protection. 59 (6) 596-600.
		Irradiating mechanically deboned chicken meat with 2.00 kGy	<i>L. monocytogens</i> is reduced 4 log units.	Radomyski, T., E.A. Murano, D.G. Olson, P.S. Murano. 1994. Elimination of pathogens of significance in food by low-dose irradiation: a review. Journal of Food Protection. 57 (1) 73-86.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Irradiation	B – <i>A. hydrophilia</i> survival and growth	Irradiating vacuum packaged pork loins with 3.0 kGy, then storage at 40°F (4°C) for 42 days	<i>A. hydrophilia</i> remained at less than 0.30 log units on irradiated loins whereas it grew to 2.51 log units on the non-irradiated loins.	Radomyski et al. 1994, cont'
	B – <i>Yersinia</i> spp. survival and growth	Irradiating chicken carcasses with 2.5 kGy then storage at 40°F (4°C) for 18 days	The irradiation reduced the <i>Yersinia</i> spp. by 2 log units and counts on irradiated carcasses remained 2 log units lower than those carcasses not treated. However, <i>Yersinia</i> spp. increased by 4 log units on both irradiated and not irradiated carcasses.	



# **Thermally Processed, Commercially Sterile**

**Includes: canned products**

This category contains only physical and chemical hazards.  
These hazards are possible in all of the previous categories.



Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	C –Excessive nitrite level in product	Addition of preblended cure including sodium nitrite	“[If] using sodium nitrite diluted [to 6.25% by weight] with sodium chloride, which is received from the manufacturer with a continuing letter of guarantee, then acute nitrite toxicity is not a problem.” (due to self-limiting, high, salt concentration)	Borchert, L.L., and R. G. Cassens. 1998. Chemical hazard analysis for sodium nitrite in meat curing. American Meat Institute Foundation Paper. <a href="http://www.ag.ohio-state.edu/~meatsci/borca2.htm">http://www.ag.ohio-state.edu/~meatsci/borca2.htm</a>
		Addition of pure sodium nitrite	“Extreme caution must be exercised if pure sodium nitrite is used.” “The conservative estimate for a lethal dose in humans is 14 mg/kg, meaning the dose would be 1 g [(0.0022 lb)] for a 70 kg [(154 lb)] adult and 0.2 g [(8.8x10 <sup>-5</sup> lb)] for a 15 kg [(33 lb)] child.”	
		Addition of sodium nitrite	Sodium Nitrite can be added up to 200 parts per million (or an equivalent of potassium nitrite) in the final product except in bacon where it can be added up to 120 ppm ingoing.	CFR 318.7(c)  To access on the internet:  <a href="http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301">http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301</a>





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